UMASS/AMHERST

312066005806185

SHOUT
SHARE
IT

UNIVERSITY OF MASSACHUSETTS
LIBRARY

S
73
E4
NO.311-345

THIS BOOK-PLATE IS A GIFT OF DR. WILLIAM GOODELL

DATE DUE

MAY 23 '66
OCT 21 '66
MAR 4 '68

GAYLORD
PRINTED IN U.S.A.

311

AGRICULTURAL BRANCH LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 311 July, 1934

Infectious Laryngotracheitis Vaccination

By Charles S. Gibbs

LIBRARY
MASSACHUSETTS
AMHERST, MASS.

The loss from infectious laryngotracheitis in poultry flocks in the State of Massachusetts is a matter of much economic concern. An interest in the control of this disease has resulted in field and laboratory experiments to develop a satisfactory method of producing immunity through vaccination. The methods and conditions under which such vaccination is practicable are here presented.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

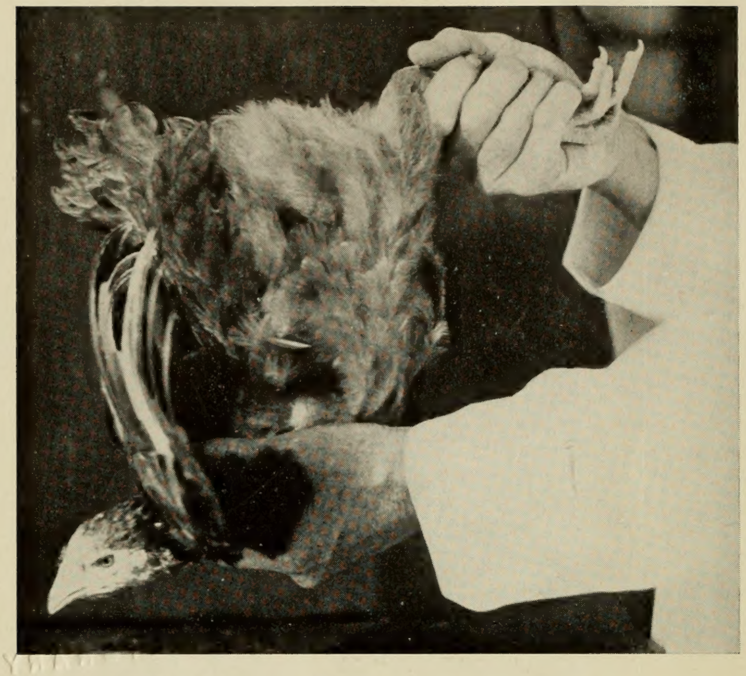


Figure 1. The Proper Way to Hold a Bird for Vaccination.

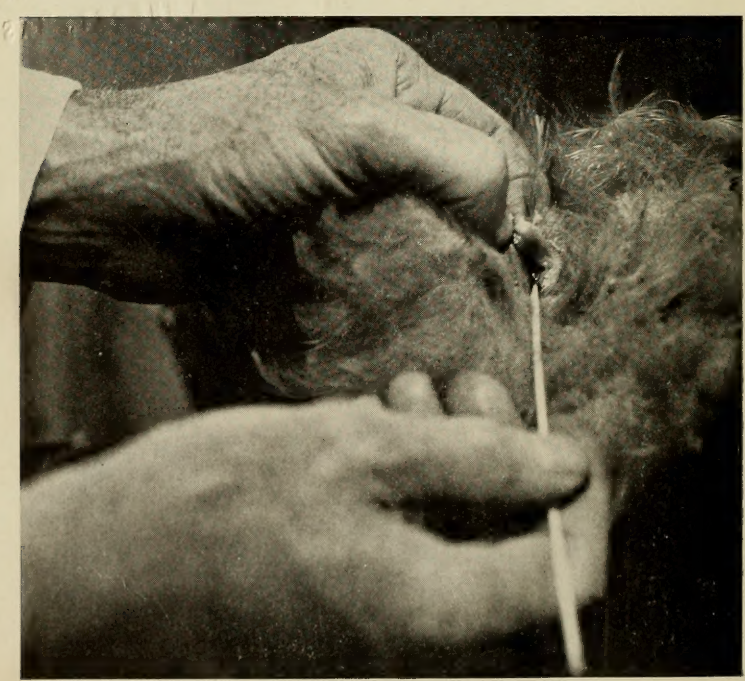


Figure 2. The Bursal Groove and the Aperture Leading into the Bursa of Fabricius, Exposed for Vaccination.

639
.2
M38b
no. 311-345

INFECTIOUS LARYNGOTRACHEITIS VACCINATION

By Charles S. Gibbs,[1]
Research Professor of Veterinary Science

This bulletin is a continuation of a previous study (Gibbs, 1933b) which should be consulted for a knowledge of the immunology of infectious laryngotracheitis as demonstrated up to the present in laboratory and field experiments. Its object is primarily to record the results of certain field experiments which were conducted in Worcester and Norfolk Counties during the summer and fall of 1933 and the winter and spring of 1934. Before attempting the field work it was necessary to make further laboratory studies in order to determine, (1) what is the most satisfactory time after vaccination to read takes; (2) what percentage of takes will insure a satisfactory degree of immunity for a vaccinated flock as a whole; (3) whether carriers are produced by vaccination. Other laboratory experiments were necessary after the field vaccinations had been completed, in the search for cloacal and bursal carriers and the study of certain other diseases resembling infectious laryngotracheitis clinically.

LABORATORY EXPERIMENTS

The Most Favorable Time For Reading Takes

It is known that the virus of infectious laryngotracheitis has special affinity for the mucous membrane of the eye, nostril, larynx, trachea, cloaca, and bursa of Fabricius. In these experiments a "take" is indicated by inflammation resulting from the inoculation of the virus into the mucous membrane of the cloaca and bursa of Fabricius.

In order to determine the most favorable time for the reading of takes, 365 birds of various ages were vaccinated and daily observations made. It was found, regardless of age, that takes were fairly evident from the third to the eighth day, and that the fourth and fifth days were the best for reading takes in a vaccinated flock, as shown in Table 1.

A Comparative Classification of Takes

The takes recorded in Table 1 were classified into five groups as shown in Table 2. From the beginning it was realized that any attempt to classify takes in vaccinated birds would have to be on a relative basis because they would grade into each other in such a manner that in many cases no sharp limits of demarcation would be evident. But this experiment had some real value in training the eye and the judgment and in developing precision and speed in reading takes under controlled conditions in the laboratory. Without this preliminary training, the field experiments might not have been satisfactory.

In this study the expression "no visible takes" indicates that the virus had no

NOV 15 1956

---

[1] The writer extends his sincere thanks to Mr. John H. Vondell of the Poultry Department of the Massachusetts State College, for taking the photographs showing the method of holding birds for vaccination against infectious laryngotracheitis.

visible effect upon the mucous membrane of either the cloaca or the bursa of Fabricius. In these cases, the mucous membrane was inflamed from rubbing, but the inflammation was transient and the mucous membrane was dry, indicating that the condition was due to the mechanical destruction of the epithelium which kept the surface moist. To the pathologist this is known as desquamative inflammation, and it was so called in this experiment.

A poor take was indicated in those cases in which the mucous membrane of the cloaca or bursa of Fabricius, or both, was moist from the exudation of mucous and serous fluids. Sometimes the feathers around the vent were moist and soiled. This was called serous inflammation.

A fair take resulted when the exudate was fibrinous and the mucous membrane showed petechial hemorrhages in the bursal groove and the opening into the bursa of Fabricius. This was designated as fibrinous inflammation.

A good take showed all of the characteristics of a fair take plus a diphtheritic plug in the opening into the bursa of Fabricius and ecchymosis of the mucous membrane of the bursal groove. This is mild diphtheritic inflammation, and a good take differed from an excellent take only in the severity of the inflammation.

An excellent take showed not only a diphtheritic plug in the opening into the bursa of Fabricius, but pseudomembrane on the mucous membrane of the bursal groove similar to that occurring in the larynx and trachea of birds suffering from natural infections. Sometimes hyperemia and hemorrhage of the mucous membrane of the bursal groove and bursa of Fabricius were evident. This condition would be designated by pathologists either as severe diphtheritic or as hemorrhagic inflammation depending upon the condition most evident.

It should be noted that most of the excellent takes occurred in the pullets and cockerels 4–7 months old and that the chickens 1–3 months old were second, while the hens and roosters 8–12 months old were third. This indicates that, under the conditions of the experiment, the best time to vaccinate is between 4 and 7 months of age.

TABLE 1. THE NUMBER OF DAYS AFTER VACCINATION IN WHICH TAKES WERE EVIDENT.

Days after Vaccination	Number of Takes Shown by Birds of Different Ages			
	1–3 months	4–7 months	8–12 months	Total
1	0	0	0	0
2	0	0	0	0
3	10	8	9	27
4	50	57	45	152
5	47	50	46	143
6	10	7	15	32
7	0	0	0	0
8	0	0	0	0
Total Takes	117	122	115	354
No Visible Takes	8	3	10	21
Total Birds	125	125	125	375

TABLE 2. A COMPARATIVE CLASSIFICATION OF TAKES

Number of Birds	Age in Months	No. Visible Takes	Number of Takes			
			Poor	Fair	Good	Excellent
125	1– 3	8	8	15	40	54
125	4– 7	3	1	11	30	80
125	8–12	10	10	25	40	40
375		21	19	51	110	174

Invisible Takes

It should be noted in Tables 1 and 2 that there were 21 birds in which no visible takes appeared. Since the bursa of Fabricius had completely involuted in the hens and roosters and was represented only by a bursal fold, the 10 birds not reacting to the vaccination in this group may have been naturally resistant to the disease. Just what part natural resistance plays in infectious laryngotracheitis has not been fully determined, although there is some evidence to indicate that it may be an important factor in baby chicks receiving nourishment from the yolk-sac and adult birds eight months or older.

In this experiment 200 chickens corresponding to the 1–3 and the 4–7 months old groups recorded in Tables 1 and 2 were vaccinated. The chickens were killed on the fifth day following vaccination, and necropsied for evidence of takes, special attention being paid to the bursa of Fabricius. The results are given in Table 3.

This table shows that six takes invisible to the eye occurred in the bursa of Fabricius in the first group, and three in the second. These numbers correspond approximately to the numbers eight and three indicating no visible takes in Tables 1 and 2.

TABLE 3. A COMPARATIVE STUDY OF TAKES IN THE BURSA OF FABRICIUS AND CLOACA.

Number of Birds	Age in Months	Number of Takes			
		Cloaca		Bursa	
		Visible	Invisible	Visible	Invisible
100	1–3	94	0	94	6
100	4–7	97	0	97	3
200		191	0	191	9

What Is a Satisfactory Degree of Immunity for a Flock as a Whole?

From the studies reported in Tables 1 and 3, the percentages of takes that would insure a satisfactory degree of immunity for a flock as a whole were computed from the visible lesions as follows:

Number of Birds	Age in Months	Satisfactory Percentage of Takes
225	1– 3	93.8
225	4– 7	97.3
125	8–12	90.0

It was tentatively concluded from this computation that flocks ranging in age from one to three months could be considered satisfactorily vaccinated against infectious laryngotracheitis if 94 percent of takes were secured for the flock as a whole, 97 percent for those four to seven months old, and 90 percent for hens and roosters.

While these conclusions were logical and backed by scientific results, there were other factors such as the duration of immunity and the production of laryngotracheal carriers in vaccinated flocks that might operate under field conditions and have some influence on the final results. The reason for believing that this experiment should not be considered as final is based on a previous study (Gibbs, 1933b) in which it was found that immunity was not lasting in birds receiving small doses of filtered virus intravenously, and that laryngotracheal carriers were produced in flocks by vaccination Just what result would ensue from two such diametrically opposed forces as these operating in a vaccinated flock could only be imagined, since no experimental work had ever been done with such a flock.

With the object in view of determining just what would happen when the immunity began to wear off in some of the birds in a vaccinated flock in which there were carriers, the 70 birds showing poor and fair takes in Table 2 were placed in a colony house with five known infectious laryngotracheitis carriers.

After two months the immunity began to wear off in the vaccinated birds. As soon as any of the birds were observed coughing, sneezing or gasping, the larynx and trachea were swabbed, and the exudate inoculated intratracheally into susceptible chickens. In this way, 17 of the 25 birds observed coughing and sneezing were found to be carriers for indefinite periods of time as shown in Table 4. It was impossible to test the birds not showing acute symptoms of

TABLE 4. LARYNGOTRACHEAL CARRIERS FOLLOWING A REINFECTION OF INFECTIOUS LARYNGOTRACHEITIS IN A VACCINATED FLOCK.

Days After Vaccination	Carriers	Non-Carriers
1	8	17
4	10	15
8	12	13
12	15	10
16	13	12
20	9	16
24	6	19
28	2	23
32	1	24
36	0	25

reinfection at this time because the forces of infection and resistance which were being studied moved so rapidly.

However, further investigation after the relapse had cleared up revealed two chronic carriers among the birds which had not shown any symptoms of infectious laryngotracheitis, except the results of the vaccination. These two birds remained carriers for a period of two months after all coughing and sneezing had ceased in the rest of the flock, and at necropsy showed lesions of infectious laryngotracheitis in the respiratory tract. One had a diphtheritic ulcer in the mucous membrane of the trachea and the other had a similar lesion in the antero-ventral rima glottis. The remaining birds showed no lesions of disease. During this experiment, the birds did not go off feed, or appear seriously affected, although considerable coughing and sneezing occurred during the period of reinfection.

This experiment indicates that the percentage of takes computed from Tables 1 and 3 insured a satisfactory degree of immunity for the flock as a whole, although a mild outbreak occurred later in those birds showing poor takes. However, the susceptible birds contracted the disease from the carriers in a mild form, thus completing their immunity.

Cloacal and Bursal Carriers in Laboratory Experiments

In a previous experiment (Gibbs, 1933b) neither cloacal nor bursal carriers were found in 52 birds five months after vaccination. Such carriers would be important if they exist, for the virus would be located in a region from which it could be most readily transmitted to other birds in the same flock. However, since the cloaca and bursa of Fabricius are subject to comparatively rapid growth and development, it may be that it is impossible for the virus of infectious laryngotracheitis to maintain a foothold in the mucous membrane of these organs to constitute chronic carriers.

TABLE 5. LENGTH OF TIME IN WHICH VIRUS WAS RECOVERED FROM VISIBLE TAKES.

Days after Vaccination	Number of Visible Takes	Number of Birds from Which Virus Was Recovered from—	
		Cloaca and Bursa	Larynx and Trachea
1	0	30	0
2	0	30	0
3	25	30	2
4	30	30	2
5	30	30	2
6	22	25	2
7	15	23	2
8	8	15	1
9	5	8	1
10	3	2	1
11	0	1	1
12	0	0	1
13	0	0	1
14	0	0	1

Since our knowledge on this point is so meager, it was decided to set up one more experiment before attempting field work. In this investigation 30 pullets and cockerels three months of age were vaccinated in the usual manner and most of the takes appeared on the fourth and fifth days as shown in Table 5. The virus was present in the cloaca and bursa of Fabricius of all the birds the first four days, after which it began to disappear in some of the birds. At the end of the eleventh day, the virus had entirely disappeared from the cloaca and bursa of Fabricius of all of the birds. Two of the birds, however, developed natural attacks of the disease, the virus appearing in the respiratory tract on the third day and remaining in one case for five days, while the other became a chronic carrier for at least two months. No evidence was produced by this experiment to indicate that cloacal or bursal carriers are produced by vaccination against infectious laryngotracheitis, but laryngotracheal carriers may result from natural attacks of the disease. None of the vaccinated birds died, while four of the five controls inoculated intratracheally with the same virus died.

FIELD EXPERIMENTS

After the completion of the laboratory studies, which showed that vaccination against infectious laryngotracheitis is a possibility and that it may have some use on the poultry farm as a preventive, the following field experiments were carried out to determine its value under range conditions. Results are shown in Table 6.

Flock 1

This mixed flock of 1,402 birds was vaccinated on July 3, 1933, in seven and one-half hours. The birds were confined in the colony houses the night before. There were four helpers, two of whom caught the birds and passed them out while the other two held them for vaccination.

The vaccine was prepared by the modified Swift method eight months before use and stored in a Frigidaire. Immediately before vaccination the vaccine was ground up into a thin paste, using glycerine and saline as a diluent, in an unglazed mortar with an unglazed pestle.

Four days after vaccination the birds were examined for takes. At this time those birds showing poor takes or none were revaccinated from those presenting good and excellent takes.

This flock passed through the winter of 1933-1934 without infectious laryngotracheitis. This is the first time in four years that this disease has not appeared on this farm in the late fall or early winter and been responsible for considerable mortality and loss in egg production.

Flock 2

This flock consisted of 912 birds. The vaccine was prepared by the modified Swift method six months before vaccination, sealed in test tubes, and stored in a Frigidaire until carried to the farm. Vaccination commenced at noon, July 10, 1933, but had to be discontinued at 2:00 p. m. on account of rain. The job was finished at noon the next day, making a six-hour task. Four days after vaccination the birds were examined for takes.

Group 1 passed through the winter without incident. The percentage of takes in this group was 93.13. Group 2 had a slight outbreak of the disease soon after moving into the laying houses in September. None of the birds died and the laying, which had just begun, was not noticeably affected. The percentage of takes in this group was 83.43, and as near as could be determined about 10 percent of the birds were affected. Since 10 percent of the vaccinated birds had either poor or no visible takes, it is reasonable to assume that as immunity wore off in this group, the susceptible birds contracted the disease from carriers, thus completing their protection against infectious laryngotracheitis.

A small flock of White Leghorns which was overlooked at the time of vaccination contracted the disease soon after being moved into the laying houses and about half of them died as a result of exposure to the vaccinated birds, although the latter showed no symptoms of disease at this time. This indicates that carriers were present in the vaccinated flock, and the White Leghorns contracted the disease from them.

Flock 3

This flock consisting of 450 pullets and cockerels was vaccinated in the forenoon of July 19, 1933. The vaccine was prepared according to the modified Swift method the day before vaccination. The birds in this flock were examined for takes five days after vaccination. The percentage of takes following the first vaccination were so high that second treatment was considered unnecessary by the owner. A cockerel in which no visible take was evident after vaccination died of infectious laryngotracheitis. The rest of the birds came through the year without showing any indications of the disease.

Flock 4

This flock consisted of 4,040 birds. Since the laboratory was not equipped to prepare vaccine for so many birds, it was decided to vary the method in order to meet the situation. Only enough vaccine was prepared in the laboratory to vaccinate 50 birds. The only object in preparing vaccine by the modified Swift method is to preserve it for use at a later time and for transportation. The treatment does not add anything to its properties; as a matter of fact such vaccines may be entirely unsatisfactory due to faulty desiccation. Theoretically, fresh vaccines prepared on the farm should be more virulent, insure a higher percentage of takes, and eliminate all possibility of poor vaccine, because if the virulence of the vaccine should prove to be unsatisfactory in the inoculated birds, it would not be used by anybody having practical experience with this method of producing immunity.

Accordingly 50 pullets and cockerels were culled from Flock 4 and confined in a colony house some distance from all other birds. These birds were inoculated intratracheally with the desiccated virus September 7, 1933. On September 11 the owner telephoned that the inoculated birds were coming down with the disease and judging by the severity of the symptoms the virus was satisfactory for vaccine. Hence it was agreed to begin vaccinating the next day.

On September 12 a dozen of the most marked clinical cases were selected from the inoculated flock, six in the morning and six in the afternoon, and fresh liquid vaccine prepared in the usual manner from the tracheal exudate. On this day 1,021 birds were vaccinated. The next day 1,535 birds were vaccinated using

TABLE 6. RESULTS OF THE VACCINATION OF FLOCKS IN THE FIELD.

Group	Number of Birds	Age in Weeks	Number of Takes				Total Percentage of Takes
			First Vaccination		Second Vaccination		
			+	0	+	0	
			Flock 1				
1	12	2	9	3	1	2	80.33
2	62	6	56	6	4	2	95.15
3	400	12	364	36	18	18	95.50
4	400	16	375	25	10	15	96.25
5	528	22	490	38	13	25	95.26
Total	1,402		1,294	108	46	62	95.58
			Flock 2				
1	481	10	442	39	6	33	93.13
2	431	20	347	84	14	70	83.73
Total	912		789	123	20	103	88.71
			Flock 3				
1	150	9	148	2	—	—	98.66
2	150	12	149	1	—	—	99.33
3	150	17	150	0	—	—	100.00
Total	450		447	3	—	—	99.33
			Flock 4				
1	1,021	16	1,008	13	3	10	99.02
2	1,535	18	1,520	15	4	11	98.63
3	284	18	279	5	1	4	98.59
4	1,200	20	1,167	33	26	7	99.42
Total	4,040		3,974	66	34	32	99.21
			Flock 6				
1	1,200	32	1,040	160*	3**	157	86.92
2	1,200	29	1,195	5	0	5	99.58
3	1,200	24	1,192	8	0	8	99.33
Total	3,600		3,427	173	3	170	95.27
			Flock 7				
1	800	20	768	32	—	—	96.00

*Of these birds 30 died as the disease had appeared two days before vaccination in two pens.

**Takes for the second vaccination were estimated, since only part of the birds were examined.

the exudate from 12 infected pullets and cockerels. On the 14th, 284 birds were vaccinated before the work had to be given up on account of rain. The vaccine left over from the birds that had been slaughtered was used to inoculate 12 more culls in order to insure a fresh supply of virus for use later. The rain continued until the afternoon of the 17th. The next day was fair and the remaining 1,200 birds were vaccinated with fresh liquid vaccine prepared from the last lot of inoculated culls.

During the three rainy days the unvaccinated birds were in a field about 50 yards from the last lot of vaccinated pullets. Largely on account of the rain the birds stayed in the colony houses most of the time. One colony house of 125 cockerels was more active than the pullets, and it was noticed that some of these cockerels were showing symptoms of infectious laryngotracheitis on the day the vaccination was recommenced. Some of these cockerels had natural outbreaks of infectious laryngotracheitis and some died. The other birds came through the year without incident.

Flock 5

This flock was not vaccinated, but it is closely related to the field experiments, and demonstrated far more conclusively than any set laboratory experiment possibly could the existence and dangers of carriers in vaccinated flocks. The history of this flock is somewhat vague and indefinite because records were not made at the time developments occurred, but it is sufficient to indicate the points suggested.

Flock 5 was visited February 9, 1934. Many of the hens showed active symptoms of infectious laryngotracheitis and some were dying. The caretaker reported that he was carrying out 15 or 20 dead hens per day. The roosters had swollen wattles and combs, but this appeared to be due to freezing and secondary infection. Cholera was excluded from the diagnosis by bacteriological examination of both roosters and hens. Two of the roosters were sick from the absorption of toxins from the edematous wattles, and one was reported as having died. The two sick roosters had been taking severe punishment from the others and were in bad shape. However they recovered in 24 hours after being removed from the flock and having the combs and wattles lanced.

The first lot of roosters had been purchased December 24, 1933, and the next lot two weeks later, or January 6, 1934. Infectious laryngotracheitis appeared soon after the second lot of roosters was added to the flock, although the exact date of the beginning of this outbreak is unknown. The pullets. 500 in number, had been purchased from a flock that has never had infectious laryngotracheitis. The evidence was against the roosters. Consequently the 64 living roosters were tested for carriers by inoculating exudate from the larynx and trachea into the larynx and trachea of susceptible chickens. Two susceptible chickens were inoculated from each rooster. This made a total of 128 chickens on the test. Of these chickens 124 remained healthy for 10 days, and four died from two of the roosters, one on the fourth day, two on the fifth, and one on the sixth. The test was repeated two weeks later with the same results, except that all four of the chickens were found dead on the fourth day.

The results of this experiment indicate that two chronic carriers of infectious laryngotracheitis were sold into a healthy flock as a result of the purchase of vaccinated birds. Of course it may be argued that this might have happened anyway, because for a number of years the flock from which the roosters were purchased had had an outbreak of infectious laryngotracheitis every fall, which lasted nearly all winter, and the disease was first introduced into this flock by the purchase of breeding cockerels, before vaccination against this disease was known.

It is evident that adult birds from vaccinated flocks and from flocks having natural outbreaks of infectious laryngotracheitis should not be placed in flocks free of this disease, because of the danger of carriers. Unfortunately no satisfactory way of detecting chronic carriers of infectious laryngotracheitis is known at present.

Flock 6

The owner of this flock had attempted the eradication and control plan, but apparently the premises were not properly disinfected and the disease broke out almost simultaneously in two different pens after about two-thirds of the pullets had been moved in from the range. No vaccine was available to treat the flock, so it was decided to attempt to stop the disease by making up the vaccine on the farm from the virus occurring naturally in the outbreak.

It took four men three days to vaccinate this flock of 3,600 birds at the rate of 1,200 per day, working eight hours a day.

Other observations, besides those recorded in Table 6, were made on the vaccinated birds, as follows:

(1) 3,100 or 86.11 percent showed takes and no symptoms of disease.

(2) 330 or 9.16 percent showed both takes and symptoms of infectious laryngotracheitis, and 10 or 3.03 percent of them died.

(3) 134 or 3.74 percent showed no takes and no symptoms of disease.

(4) 36 or 1.00 percent showed no takes and symptoms of disease, and 20 or 55.55 percent died.

Flock 7

August 7, 1933, the writer visited a poultry farm on which an outbreak of infectious laryngotracheitis had just begun. This poultryman had started in the business the year before by purchasing pullets and cockerels from breeders and bringing them together in a single house. Infectious laryngotracheitis broke out soon after the birds were housed and lasted all winter, so that the owner decided to slaughter the birds for local trade.

A new house was built about 10 feet from the one in which some of the old birds still remaining on the farm were kept, and the first lot of pullets which had begun to lay had been placed in it 10 days before developing an outbreak of infectious laryngotracheitis. In the meantime, the disease appeared in some of the chickens on the range, which was about 20 feet from the new poultry house. There were approximately 800 chickens on the range.

It was decided to vaccinate the chickens using vaccine prepared from the pullets which had contracted the disease first and were hopelessly lost, since all of them were sick, a few had died, and about half of those remaining probably would die in the next three or four days. Unfortunately the writer did not have his vaccination outfit with him as the trip was taken for an entirely different purpose, and it was necessary to use improvised equipment. The applicators were split from kindling in the wood pile, cotton for making swabs was secured from the family medicine closet, scissors from the sewing room, a bowl and a little water from the kitchen. With this crude equipment the writer, the owner, and a man hired for the occasion set out to save the chickens on the range from dying of infectious laryngotracheitis. Thirty of the pullets showing marked symptoms of infectious laryngotracheitis were sacrificed to make vaccine, and the 800 chickens on the range were vaccinated in the cloaca and bursa of Fabricius. Five days later the flock was examined for takes, with results recorded in Table 6.

In addition it was estimated at the time the birds were examined for takes that:

(1) 704 or 88 percent showed takes and no symptoms of disease.
(2) 64 or 8 percent showed both takes and symptoms of disease.
(3) 28 or 3.5 percent showed no takes and no symptoms of disease.
(4) 4 or 0.5 percent showed no takes and symptoms of disease.

All of the birds recovered and remained free of infectious laryngotracheitis through the year except the four which showed no takes and symptoms of disease. The birds not showing takes were not revaccinated at the time the examination for takes was made and the results were entirely satisfactory to the poultryman.

Cloacal and Bursal Carriers in Field Experiments

After the field vaccinations had been completed it was felt that the presence or absence of cloacal and bursal carriers in vaccinated flocks was still unsettled, because the studies hitherto had been limited to one group of 55 birds (Gibbs, 1933b) and another group of 30, which may not have been sufficient to give a correct interpretation. So 620 birds from Flock 4 were systematically examined for cloacal and bursal carriers beginning two months after vaccination. This flock was divided into four groups of 155 birds. Each group was swabbed in the cloaca and bursa, and chickens inoculated intratracheally with the exudate until all of the birds had been examined.

The cloacas and bursas of 560 hens and 40 roosters were found to be free of microorganisms or viruses pathogenic to baby chicks. The chickens inoculated from these hens and roosters remained healthy throughout the experiment. The cloacas and bursas of 20 of the hens may not have been free of microorganisms or viruses, because the chickens inoculated from them developed dyspnea and died of asphyxiation as in infectious laryngotracheitis. After death the larynx and trachea were found plugged with pseudomembrane. Histological studies of the larynx and trachea of the diseased chicks indicated that the inflammation was a desquamative epithelial inflammation. The disease could not be transmitted beyond the first group of chickens inoculated directly from the hens. No bacteria other than those occurring normally in the larynx and trachea could be found. The disease was not obtained by swabbing the tracheas of chickens with clean swabs. It occurred in the same proportion in a smaller number of unvaccinated hens. Therefore the disease did not appear to be traumatic or confined to vaccinated birds. The specific cause was not determined, although it occurred quite regularly in the same birds, as the following study shows.

Four groups of chickens were inoculated at different intervals with exudate from 10 vaccinated and 10 unvaccinated birds showing the disease, and from 10 vaccinated and 10 unvaccinated birds not showing the disease. Results are shown in Table 7.

A study of Table 7 shows that the disease was more persistent in the unvaccinated birds, but evidence was lacking to indicate that vaccination had anything to do with it. The disease was probably due to a bacterium or virus which grew in the cloaca of the fowl but did not grow on the culture media used in this study, and either did not grow or did not maintain its virulence in the respiratory tract of the chickens beyond the first inoculation.

TABLE 7. INOCULATION EXPERIMENTS IN AN UNUSUAL DISEASE OF THE CLOACA AND BURSA OF FABRICIUS OF THE DOMESTIC FOWL.

Intervals in Weeks	Hens Showing the Disease		Hens Not Showing the Disease	
	Vaccinated	Unvaccinated	Vaccinated	Unvaccinated
1	10	10	10	10
2	10	10	9	10
3	9	10	9	10
4	10	10	9	10
Total	39	40	37	40

Since the cloaca and bursa of Fabricius undergo rather radical changes in the growth of the chicken, it is anticipated from this and preceding studies that cloacal and bursal carriers of infectious laryngotracheitis may not exist for any great length of time. As the chicken grows, the mucous membrane of the cloaca is subject to the passage of excretions in both sexes, and the laying of eggs in pullets. These functions tend to thicken the mucous membrane and make it firmer and more resistant to mechanical injury, as well as to the attacks of microorganisms and viruses. At five or six months of age, the bursa of Fabricius undergoes involution in the course of which this organ disappears entirely and is replaced by a bursal fold. The mucous membrane of the bursal fold is firmer in consistency and more resistant to the virus of infectious laryngotracheitis than that of the bursa of Fabricius.

DISEASES SOMETIMES MISTAKEN FOR INFECTIOUS LARYNGOTRACHEITIS

During the course of four years and a half of field investigations, representative cases from 131 epizootics have been studied, and some diseases simulating infectious laryngotracheitis clinically have been found. Laboratory studies revealed that these diseases are etiologically and immunologically different. Infectious laryngotracheitis was not only the most important from a mortality point of view, but it appeared to be the most common, as the following summary shows:

Coryza and colds	14
Conjunctivitis	5
Rhinosinusitis	3
Infectious bronchitis	2
Chickenpox and roup	4
Infectious laryngotracheitis	103
Total	131

These diseases were maintained in healthy birds in the laboratory either by contact or by inoculation with the respective exudates. In making the etiological studies, exudates were streaked on plates containing chicken infusion and chicken blood agar, and incubated aerobically, anaerobically, and in an atmosphere of CO_2, or sealed as Nelson (1933) found suitable for cultivating the causative agent in coryza of chickens, and as Delaplane and Stuart (1934), Schalm and Beach (1934), and Eliot and Lewis (1934) found efficacious for isolating an organism involved in purulent conjunctivitis, rhinosinusitis, and colds of chickens. Immunological studies were made on birds recovering from natural attacks of the respective diseases. The diagnostic differentiation of these diseases is especially important because of the bearing it has on vaccination against infectious laryngotracheitis.

Coryza and Colds

A gram negative hemophilic bacterium resembling those described by the investigators just mentioned was found in 8 of the 14 diseases classified as coryza and colds. The causative agent in this disease did not appear to be filtrable. Berkefeld V, N, W, and Seitz filters were used according to the technique of Ward (1928), Tang (1932), and Gibbs (1933b). All of the filters used in this study were tested and graded according to the technique of Ward and Tang (1929) and Krueger and Riter (1930).

The hemophilic bacterium did not appear to be as virulent in chickens reared in the laboratory as in field cases. Other factors such as exposure to cold, damp weather and improper feeding may have been responsible for these differences. Before this microorganism is accepted as the primary cause of coryza and colds in the domestic fowl, more intensive investigations of natural outbreaks are in order.

Fresh exudate from the nostrils and sinuses of chickens suffering from coryza or colds was swabbed into the bursa of Fabricius and produced mild inflammation of this organ as shown in birds necropsied five days after inoculation. Freshly isolated cultures of *Hemophilus gallinarum* induced a similar affection, while old laboratory cultures seemed to be quite innocuous. Chickens in which takes were evident retained their resistance to this disease for one month. Hens and roosters, or birds in which the bursa of Fabricius had disappeared, were refractory to this treatment.

Conjunctivitis

Five outbreaks of conjunctivitis in chickens six weeks or less in age were found, after several transfers in susceptible chicks, to be chronic eye forms of infectious laryngotracheitis. The poultrymen called this condition "greasy head" because the chickens frequently rubbed their heads on their shoulders, and the head, neck, and shoulders became smeared with exudate from the eyes, producing a very unsightly appearance.

Rhinosinusitis

Three outbreaks of rhinosinusitis occurring in Bristol and Plymouth Counties were found upon etiological studies to be due to mixed infections. One outbreak appeared to be due to a combination of coryza and infectious laryngotracheitis, since *Hemophilus gallinarum* (Eliot and Lewis, 1934) was isolated in cultures and a virus indistinguishable from that producing infectious laryngotracheitis in susceptible birds after filtration with Berkefeld V filters. *Hemophilus gallinarum* and *Streptococcus bronchitis* (Gibbs, 1933a) were isolated from affected birds in the other two outbreaks, and the disease reproduced in healthy laboratory stock by instilling mixed suspensions of these microorganisms into the eyes and nostrils.

Preliminary experiments indicate that rhinosinusitis may be controlled by autogenous vaccination, using the technique recommended for autogenous vaccination in infectious laryngotracheitis.

Infectious Bronchitis

Two outbreaks of infectious bronchitis have been identified. One was in a flock of brooder chickens and the other was in a flock of roosters which had been housed by themselves. The disease did not appear to be especially serious in either the chickens or adult birds, and finally disappeared without treatment. Since infectious bronchitis appears to be relatively unimportant, and the location of the symptoms in the bronchi and bronchioles is rather inaccessible, no curative treatment is suggested for adult birds. However, the brooder should be thoroughly cleaned before being used again when the disease appears in chickens.

Chickenpox and Roup

Four outbreaks of chickenpox complicated with roup appeared in this study of field cases. These epizootics were in small chickens and rather difficult to diagnose at first sight. However, upon close examination characteristic pustules were found either on the edges of the beak or on the comb of some of the chickens, and satisfactory diagnosis made. Since chickenpox is a cutaneous disease and may be controlled by specific vaccination, these cases were not extensively studied.

WHEN AND HOW TO VACCINATE FOR INFECTIOUS LARYNGOTRACHEITIS

The Massachusetts Plan for the Eradication and Control of Infectious Laryngotracheitis (Gibbs, 1933c) is the most hopeful for the industry as a whole, because it will eliminate not only infectious laryngotracheitis but all contact diseases. This plan will never succeed unless the poultry associations get back of it and put it across. There is no money in this plan for commercial firms as there is in vaccines. Therefore commercial concerns will not put this plan into operation, but some of them will be led into the manufacture and sale of vaccines. There is undoubtedly a place for infectious laryngotracheitis vaccines for they enable the poultryman, so unfortunate as to have an infected flock, to save his birds until a more favorable time is reached for the complete eradication and control of the disease by sanitary methods.

Also it has been found (Gibbs, 1931b) that infectious laryngotracheitis is spread by both acute cases and chronic carriers, and vaccination does not eliminate the possibility of the spread of the disease from either of these sources, because vaccination is nothing more than the inoculation of the mucous membrane of the cloaca and bursa of Fabricius with the living virus and the symptoms and lesions are confined to these organs rather than the larynx and trachea. In natural outbreaks birds die of asphyxiation due to the plugging of the larynx and trachea. Properly vaccinated birds do not die because the larynx and trachea are unaffected; yet the birds have the disease and immunity is developed the same as in natural outbreaks. It should not be forgotten that as long as acute cases and chronic carriers remain on the premises there is always danger of the spread of the disease to susceptible birds.

The conditions under which vaccination may reasonably be expected to be successful are as follows: First, the virus from which the vaccine is made must be virulent. This is indicated by the way the disease attacks the birds sacrificed for vaccine. It should always kill some of them in three or four days after inoculation or infection. Second, it is no use to vaccinate birds already sick with infectious laryngotracheitis. If the disease is pretty well scattered through the whole flock, field tests indicate that it is useless to vaccinate. Also, birds badly infested with worms or in a run-down condition generally are poor risks for vaccination. *Under no circumstances should a flock be vaccinated against infectious laryngotracheitis unless the disease is already present on the farm and there is imminent danger of its spreading to susceptible birds.*

Preparation of Vaccine

When it is desired to vaccinate chickens on the range, laboratory vaccine may be used. Since it is difficult to prepare infectious laryngotracheitis vaccine in the laboratory on a large scale, and at the same time maintain a satisfactory degree of virulence in every batch, it is well to test such vaccines before use. One way to do this is to isolate some birds from the main flock and inoculate them intratracheally with the vaccine. If most of the birds come down with infectious laryngotracheitis within three days and some of them die, the virulence is satisfactory and the vaccine may be used. But if the vaccine should prove to be unsatisfactory, the birds should be destroyed and the premises thoroughly cleaned and disinfected taking special care not to let the disease reach the main flock. The secret of success in vaccinating against infectious laryngotracheitis is a satisfactory vaccine in the hands of an experienced worker.

If infectious laryngotracheitis has already appeared in a small portion of the flock and its virulence is satisfactory for immunization, then autogenous vaccine should be used. Autogenous vaccine may be prepared as follows: Take a bird that has just died or one that is very sick and kill it. Lay the dead bird on a table, box, or barrel, on its back, and beginning at the beak slit open the skin of the neck with a pair of scissors, exposing the windpipe to the wish-bone. Carefully dissect the windpipe from the other tissues, taking care to get as much of it as possible. Now slit the windpipe open, beginning at the larynx and cutting clear through to the other end; and, by means of a small knife—a paring knife, a pen knife, or a scalpel—scrape the exudate from the exposed larynx and trachea and put it in a bowl or mortar. After the desired amount of exudate has been secured, grind or triturate it with a smooth stick or pestle, adding a little cold water or a mixture of glycerine and saline until a thin, paste-like mass is formed. This is the vaccine. If it has been properly prepared from birds sick or dead of infectious laryngotracheitis, it should be more virulent than any that can be purchased because it is fresh. Furthermore, it is autogenous, and should be specific for the particular disease that the birds are affected with. In order to get the best results, fresh vaccine should be made from the sick birds every two hours, and any that is left over after vaccination destroyed. It will require some planning in order to make vaccine and birds to be vaccinated come out even.

Poultrymen should not indulge in the practice of borrowing infectious laryngotracheitis exudates from each other, for such practice will result in the spread of diseases other than infectious laryngotracheitis, and may lead to the ruination of the poultry industry in Massachusetts.

Vaccination

If the birds are housed they should be driven into a corner and held there by crates standing on end, or some other fence. On the range it is usually most convenient to fasten the required number of birds for a day's work in the roosting houses the night before. In the case of laying hens, some poultrymen with good lighting facilities prefer to have the vaccinating done at night, because then it is only necessary to lift the birds from the roosts with little disturbance and loss in production as a result of handling.

A vaccinating crew ordinarily consists of three men: one to catch the birds, one to hold the birds, and one to do the vaccinating. The first man should remain with the birds, the other two should go beyond the range of dust and where the light is good. The prepared vaccine should be on a table, box, or barrel nearby. Also some cotton should be twisted on the ends of some applicators or sticks about the size of matches or larger.

The first man catches a bird and hands it to the second man who grasps it by the legs with one hand and the wings with the other, and holds it head down and back to the third man, ready for vaccination as shown in Figure 1. The third man grasps the upper or dorsal fold of the cloaca with the thumb and forefinger, and opens the cloaca. On the upper or dorsal side of the cloaca a pink groove will be seen leading into a little fold or slit. With the other hand, he picks up an applicator, dips the cotton into the vaccine, and rubs it into this groove, going clear into the fold or slit as shown in Figure 2. This groove is the bursal groove, the fold is the bursal fold, and the slit is the opening into the bursa of Fabricius. All of these parts must be recognized and distinguished in order to vaccinate properly. As soon as the vaccine has been rubbed into the bursal groove, the bursal fold, or the bursa of Fabricius, the vaccination is complete and the bird should be placed where it cannot rejoin the unvaccinated group.

It should be pointed out that the bursa of Fabricius is usually absent in laying hens and breeding cocks. In these birds it is replaced by a bursal fold. In pullets and cockerels which have been killed and opened to expose the abdominal cavity, the bursa of Fabricius appears as a bulb-like organ dorsal to the cloaca. The mucous membrane of the bursa is soft like that of the larynx and trachea. In vaccinating pullets and cockerels the vaccine should be swabbed into the bursa of Fabricius in order to secure a lasting immunity.

The success of the vaccination depends upon the number of takes. Four days after vaccination the birds should be examined for takes. In checking up on the number of takes, the same procedure can be followed as in vaccinating the birds. The person reading the takes should have a supply of swabs handy and revaccinate any birds in which takes did not occur with exudate from birds which show good takes. A take has occurred in those birds in which the mucous membrane of the cloaca is moist, inflamed, or covered with pseudomembrane. In pullets and cockerels the opening into the bursa of Fabricius will often be plugged with pseudomembrane just as the larynx and trachea are filled in birds sick or dead of infectious laryngotracheitis.

Vaccination is a medical treatment and medical treatments have their limitations. If the limitations of infectious laryngotracheitis vaccination are appreciated, cloacal and bursal inoculation may be successfully accomplished on the poultry farm and serious loss from the disease prevented.

SUMMARY AND CONCLUSIONS

1. The success of vaccination against infectious laryngotracheitis depends on the number of takes. The most favorable time for reading takes was found to be the fourth and fifth days after vaccination. Takes may be classified, according to degree of inflammation, as poor, fair, good, or excellent. Occasionally takes occur in the bursa of Fabricius which are not visible at the time of examining the live birds.

2. It has been determined that 94 percent takes in chickens one to three months of age, 97 percent takes in pullets and cockerels four to seven months old, and 90 percent takes in hens and roosters eight to twelve months of age insure a satisfactory degree of immunity for a flock as a whole. The takes should be good, fair, or excellent, for the immunity tends to wear off in birds showing poor takes. When vaccinating is once started, it should be pushed on to completion with as little delay as possible in order to avoid outbreaks of the disease.

3. After this laboratory information had been obtained, field vaccination was successfully accomplished in six flocks, or 11,204 birds.

4. A study of diseases simulating infectious laryngotracheitis was made for differential diagnostic purposes, and it was found that autogenous vaccines were specific for infectious laryngotracheitis, coryza, and rhinosinusitis, but not for each other. Therefore, it cannot be emphasized too strongly that before vaccination is resorted to for the control of infectious laryngotracheitis, a correct diagnosis of the disease or diseases infecting the flock is necessary for success.

5. Since laboratory vaccines for infectious laryngotracheitis have not been entirely successful in the hands of poultrymen, autogenous vaccines may have some use because of their specificity and availability at the time of greatest need. A method of preparing and using autogenous vaccines in infectious laryngotracheitis is outlined. It should be understood that this method of vaccination will save the flock if properly applied, but it cannot be depended upon to eliminate carriers; and for the good of the poultry industry as a whole it should be followed by the complete eradication and sanitary control of the disease. Vaccination for infectious laryngotracheitis merely enables the poultryman to choose the time for disposing of his birds and cleaning and disinfecting the premises occupied by them. When accepted in this light, vaccination is a valuable contribution to the control of infectious laryngotracheitis.

REFERENCES

1932. DeBlieck, L. A haemoglobinophilic bacterium as the cause of contagious catarrh of the fowl. Vet. Jour. 88 (1):9-13.

1933. Delaplane, J. P., H. O. Stuart, and H. Bunyea. A preliminary report of an apparently new respiratory disease of chickens. Jour. Amer. Vet. Med. Assoc. 82, n.s. 35 (5):772-774.

1934. Delaplane, J. P., and H. O. Stuart. Rhinitis—A respiratory disease in chickens. R. I. State College Bul. 29 (4):92-94.

1934. Eliot, C. P., and M. R. Lewis. A hemophilic bacterium as a cause of infectious coryza in the fowl. Jour. Amer. Vet. Med. Assoc. 84, n. s. 37 (6):878-888.

1931a. Gibbs, C. S. Saprophytic and secondary microorganisms occurring in the respiratory tracts of domestic fowls and chickens in health and disease. Jour. Bact. 29 (2):97-109.

1931b. Gibbs, C. S. Infectious laryngotracheitis carriers. Mass. Agr. Expt. Sta. Bul. 278.

1933a. Gibbs, C. S. Bronchitis of baby chicks. Poultry Sci. 12 (1):46-48.

1933b. Gibbs, C. S. The immunology of infectious laryngotracheitis. Mass. Agr. Expt. Sta. Bul. 295.

1933c. Gibbs, C. S. The Massachusetts plan for the eradication and control of infectious laryngotracheitis. Jour. Amer. Vet. Med. Assoc. 83, n. s. 36 (2):214-217.

1930. Krueger, A. P., and R. C. Ritter. The preparation of a graded series of ultrafilters and measurement of their pore size. Jour. Gen. Physiol. 13:409-419.

1933. Nelson, J. B. Studies on an uncomplicated coryza of the domestic fowl. Jour Expt. Med. 58 (3):289-304.

1934. Schalm, O. W., and J. R. Beach. The etiology of a respiratory disease of chickens. Science 79 (2053):416-417.

1932. Tang, F. F. Absorption experiments with the virus of vaccinia. Jour. Bact. 24 (2):133-143.

1928. Ward, H. K. Further notes on the filtration of the virus of vaccinia. Jour. Expt. Med. 50:31-40.

1929. Ward, H. K., and F. F. Tang. A note on the filtration of the virus of herpetic encephalitis and of vaccinia. Jour. Expt. Med. 49 (1):1-4.

Publication of this Document Approved by Commission on Administration and Finance
3M-8-34. No. 2112

312

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 312 October, 1934

Effects of Inbreeding on Fecundity In Rhode Island Reds

By F. A. Hays

Agri. Library
File No. 2

Inbreeding has been used extensively for establishing uniformity in herds and flocks. This report covers the results of inbreeding poultry for high fecundity characters when rigid selection of female breeding stock was practiced.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

EFFECTS OF INBREEDING ON FECUNDITY IN RHODE ISLAND REDS

By F. A. Hays, Research Professor of Poultry Husbandry

INTRODUCTION

Two experiments previously reported by Hays (1924 and 1929) have shown that inbreeding reduces egg production. The birds in these experiments failed to exhibit many of the characters that make high production possible. In view of these results it is conceivable that the standards for selecting the foundation stock as well as for the selection of breeders each year were not so rigid but that many undesirable characters became intensified through inbreeding. In order to overcome these possible defects, a new experiment was started in the spring of 1929 using very rigid standards of selection.

The new project was made up of three lines of essentially unrelated birds. Line A breeding pen consisted of three groups of three full sisters each. These three groups of sisters had the same sire, but their dams were essentially unrelated. A check group was made up of three females selected at random from the high fecundity flock but not related to the inbred birds. All females were pullets, and the entire group was mated to the sire of the inbred pullets. Line B and line C breeding pens were made up in the same general way as line A, but the birds used in each line were not related to the birds in either of the other lines.

The 1930 matings consisted of pullets from the three lines mated to a cockerel of their own line and three check pullets selected from the general flock. There was one full-brother x sister mating each in lines A and B and two in line C. The other inbred matings were half-brother x sister matings. Daughters were retained from one inbred mating (half-brother x sister) and from one check mating in each of the three lines.

The 1931 matings consisted in line A of one half-brother x sister mating and five full-brother x sister matings with three check matings. For line B there were four full-brother x sister matings and three check matings. Line C had three full-brother x sister matings and two check matings.

Matings for 1932 in line A consisted of four full-brother x sister matings, two matings with line C and two check matings. Line B was discontinued with the 1931 generation because none of the females in this generation qualified for breeding in 1932. In line C there were two full-brother x sister matings, three matings with line A birds and two check matings.

The matings of 1933 to produce the last generation were as follows: An inbred line A male was mated to one of his full sisters, to two A and C line cross females, to four check females from line C, to five check daughters from the 1932 check matings in line A, and to one female selected from the general flock. In line C a male from a cross of lines A and C was mated to four of his full sisters, to one inbred line C female, to four line C 1932 check females, and to one female from the general flock.

Standard for Selecting Female Breeders

A careful study was made of the flock as a whole to discover those families that were freest from undesirable weaknesses as far as known characters affecting egg production are concerned. The foundation stock used in this experiment was made up of the highest class of birds available with respect to known fecundity characters.

A standard for selecting pullet breeders was drawn up and followed as closely as possible throughout the experiment. Since the standard deals with the entire pullet laying year, it was necessary to place pullets in the breeding pens that had qualified up to the breeding season and to retain offspring from those that met the standard when their laying year closed.

Previous experience has shown that pullets and cockerels are more satisfactory for breeding in restricted projects where specific matings are desired. This is especially true for males where the death rate is very high, and to no small extent for females also. This explains why young untested males and females were used for breeding in this experiment, and why offspring were retained from but a small proportion of the pullet breeders used.

The standard for selecting each year was as follows:

Sexual maturity—215 days or less.
Weight at first egg—5 pounds or more.
Winter pause—not over 4 days.
Winter clutch size—2.6 or over.
Broodiness—none during the pullet year.
Persistency—315 days or more.
Hatchability—85 per cent or more.
Egg size—a minimum average of 52 grams to January 1.
Range mortality—not above 10 per cent in family.

In selecting breeding stock for a considerable number of characters, more difficulties exist than might be anticipated in an improved flock. Rather early in this experiment, it became necessary oftentimes to use birds for breeding that most nearly conformed to the standard. When, however, breeding females deviated widely from the standard set up for breeders, progeny was no longer maintained.

EXPERIMENTAL RESULTS

Character of Female Breeders

Table 1 shows the degree of conformity to the standard, by inbreds, checks, and birds from the inbred lines crossed as the experiment progressed.

Range mortality represents the death losses in families from the age of one day up to September 1. Hatching dates range at weekly intervals between March 25 and May 15 each year. All chicks were taken from the incubators at one day of age and placed in 10 x 12 portable brooder houses on the chick range. The chicks in this experiment were brooded along with other pedigreed Rhode Island Red chicks of the same age, in units of about 200. It is evident from the data obtained that the mortality rate was increasing in the inbred lines as the inbreeding became more intense, and that crossing lines A and C reduced the mortality rate in the last generation of breeding females.

Age at sexual maturity has been observed to increase under inbreeding by Dunn (1923), Dunkerly (1930), and Jull (1933); but Hays (1929 loc. cit.) failed to discover a consistent increase in age at sexual maturity when inbreeding Rhode Island Reds. This study, however, shows a rather consistent increase in the age at sexual maturity in the inbred mothers as the experiment progressed. The

TABLE 1.--PERCENTAGE OF BREEDERS QUALIFYING FOR STANDARD IN INBRED MATINGS AND CHECK MATINGS.

Year	Matings	Percentage Qualifying									Number Kept	Annual Production		Laying-House Mortality Percent
		Range Mortality not over 10%	Sexual Maturity 215 days or less	Weight at First Egg 5 lbs. or more	Winter Pause not over 4 days	Winter Clutch Size 2.6 or over	Broodiness none	Persistency 315 days or more	Hatchability 85% or more	Egg Weight to Jan. 1 Average of 52 grams		Average	Coefficient of Variability	
											Families			
1929	Inbred	33.33	96.30	88.89	59.26	81.48	86.96	91.30	11.11	96.30	6	231.04		
	Check	75.00	100.00	100.00	50.00	87.50	75.00	75.00	12.50	87.50	3	213.50		
1930	Inbred	30.77	92.31	84.62	30.77	46.15	88.89	77.78	15.38	84.62	3	183.56		
	Check	77.78	88.89	100.00	100.00	77.78	100.00	83.33	22.22	88.89	3	207.83		
1931	Inbred	0	61.54	76.92	7.69	30.77	91.67	91.67	0	61.54	2	171.83		
	Check	12.50	100.00	87.50	37.50	75.00	100.00	100.00	0	87.50	2	224.17		
1932	Inbred	46.15	53.85	100.00	23.08	15.38	87.50	12.50	9.09	61.54	2	154.00		
	Check	25.00	100.00	100.00	100.00	75.00	100.00	100.00	25.00	100.00	7	241.00		
1933	Inbred	0	66.67	33.33	33.33	33.33	.	..	0	66.67	0	....		
	Inbred Lines Crossed	100.00	100.00	100.00	16.67	83.33	100.00	50.00	33.33	100.00	4	196.50		
	Check	60.00	100.00	100.00	61.54	69.23	80.00	40.00	7.69	93.33	5	207.00		

TABLE 2.--PERCENTAGE OF OFFSPRING QUALIFYING FOR STANDARD EACH YEAR IN INBREDS AND IN CHECKS.

Year	Matings	Range Mortality not over 10%	Sexual Maturity 215 days or less	Weight at First Egg 5 lbs. or more	Winter Pause not over 4 days	Winter Clutch Size 2.6 or over	Broodiness none	Persistency 315 days or more	Hatchability 85% or more	Egg Weight to Jan. 1 Average of 52 grams	Number Kept	Average	Coefficient of Variability	Laying-House Mortality Percent
											Daughters			
1929	Inbred	19.05	50.82	78.33	32.73	20.37	97.37	52.63	15.38	72.22	63	172.29	.2049	20.63
	Check	100.00	77.78	97.22	39.39	60.60	83.33	44.44	......	42.42	38	179.00	.2402	42.11
1930	Inbred	0	56.52	78.26	17.39	26.09	95.00	80.00	0	63.64	26	170.60	.1617	11.54
	Check	78.13	84.38	81.25	38.71	58.06	100.00	87.50	33.33	68.75	32	202.75	.1798	15.63
1931	Inbred	35.29	41.18	100.00	33.33	13.33	87.50	12.50	9.09	61.54	17	154.00	.1858	25.00
	Check	52.94	88.23	100.00	88.23	82.35	78.57	85.71	0	41.18	17	227.79	.1854	11.76
1932	Inbred	0	50.00	25.00	33.33	33.33	.....	.....	0	75.00	5	......	......	100.00
	Inbred Lines Crossed	100.00	91.67	91.67	45.45	63.64	100.00	66.67	28.57	91.67	12	215.00	.1319	66.67
	Check	60.98	90.24	97.56	55.55	75.00	100.00	72.22	14.29	68.29	41	225.22	.1619	51.21
1933	Inbred	No offspring retained												
	Inbred Lines Crossed	15.38	72.73	72.73	20.00	20.00	......	......	100.00	70.00	13	......	......	......
	Check	61.77	57.70	100.00	15.79	57.90	......	......	50.00	76.19	34	......	......	......

percentage of inbred mothers that met the standard for early maturity fell as low as 53.85 per cent in 1932. When inbred lines were crossed, all of the mothers selected were genetically early maturing. The check mothers showed early maturity consistently throughout the period.

Weight at first egg is almost entirely dependent upon age at first egg in Rhode Island Reds, as Hays (1933a) has shown. This relation apparently did not hold true when inbreeding was practiced, using 5 pounds as a minimum weight. For example, all the inbred mothers used in 1932 qualified, while in 1933 only one-third of the mothers attained a 5-pound weight at first egg, which indicates that inbreeding did tend to decrease body weight. Crossing inbred lines A and C resulted in a return to satisfactory body weight. The check group of mothers showed satisfactory body weight throughout the experiment.

A cessation of egg production exceeding four days between November 1 and March 1 was considered a winter pause. The data show no consistent relation between inbreeding and the percentage of birds with winter pause. The check group of mothers was more satisfactory than the inbreds, but these failed to qualify as a whole for absence of pause in three years of the experiment. In general, inbreeding did not appear to greatly affect the proportion of birds with winter pause.

Highly intense birds will show a mean winter clutch size of 2.6 or more, according to previous studies on this flock (Hays and Sanborn 1927). The data presented in Table 1 show a progressive decrease in intensity of the inbred mothers throughout the experiment, while the intensity of the check mothers remained at a rather constant level. Crossing inbred lines A and C restored intensity to the original level of the foundation females. These results indicate clearly that inbreeding does reduce intensity of laying.

The failure of the broody instinct to appear during the first laying year indicates a low degree of broodiness, but is not a safe criterion of its absence, as Hays (1933b) showed. Since most of the birds in this experiment were retained for only one laying year, it was possible to employ only this partial criterion of the presence or absence of the broody instinct. Individuals that went broody the first year were known to carry the two complementary genes for broodiness and were selected against. The standard called for no broodiness in the pullet year, and the character of both the inbred and the check mothers remained rather stable in this respect throughout the experiment.

The proportion of highly persistent mothers had a marked falling off toward the end of the experiment in the inbred lines. Crossing two inbred lines failed to restore persistency to the level of the foundation females. The check females were satisfactory through the five years, except in the concluding year. There is no explanation for the inferior character of the check females of the last generation, other than mere chance. The data in general show a downward trend of persistency following inbreeding.

The hatchability of the foundation inbred females was unsatisfactory, since only 11.11 per cent gave a record of 85 per cent or more of fertile eggs hatched. This was followed by a still further decline as might be anticipated. In 1931 and 1933 none of the breeders qualified in hatchability. Crossing inbred lines did improve the hatchability. The check females were also an inferior lot from the standpoint of hatchability, but there was no significant decline throughout the experiment. There is, in general, a downward trend in hatchability of the inbred females used.

In mean egg weight to January 1, there is a significant decline in the inbred females. Crossing two inbred lines restored the winter egg size to its original level. Check females showed an almost constant conformity to the standard for egg size throughout the experiment. Inbreeding seemed to reduce winter egg size in this experiment.

The annual production of the inbred female breeders began with 231 eggs and showed a consistent decline to 154 eggs. Crossing inbred lines A and C increased the egg production level but not to the original figure. The check female breeders did not decline in production but were rather consistent high producers during the five-year period. Inbreeding did consistently reduce egg production because the selection of breeding females each year was based on anticipated superiority.

Character of Female Offspring Produced

All female offspring from the inbred lines, from lines A and C crossed, and from the check matings are classified in Table 2 according to the standard. The three inbred lines are combined.

The 63 first-generation daughters produced by father x daughter matings showed only about 20 per cent qualifying with a family range mortality to September 1 of less than 10 per cent. In the following year the inbred daughters came from half-brother x sister matings in the three lines, and none of these daughters came from families with a range mortality as low as 10 per cent. The third generation of inbred daughters came from one half-brother x sister mating and one full-brother x sister mating. No daughters from the first mating qualified and all daughters from the second mating qualified giving about 35 per cent of all daughters qualifying. The fourth generation of inbred daughters from one brother x sister mating and two half-brother x sister matings all exceeded 10 per cent in range mortality. No inbred daughters were retained in the last generation. It is evident that range mortality did increase under inbreeding.

Check daughters showed a variable percentage qualifying for low range mortality. The minimum figure was about 53 per cent and this occurred in 1931 Two later generations of check daughters showed 61 and 62 percent qualifying.

Crossing inbred lines in 1932 gave only daughters with low range mortality, while in 1933 mortality in such daughters rose to a very high figure.

The age at sexual maturity of the inbred daughters did not change significantly in four generations. Crossing inbred lines in two generations greatly increased the percentage of early maturing daughters as compared with the inbreds. The check daughters showed a higher percentage of early maturing birds than the inbreds in every generation. These data indicate in a rather limited way that inbreeding does immediately retard sexual maturity but that continued inbreeding does not increase this effect.

Inbreeding had little effect on the weight at first egg. The last generation of inbreds showed only 25 per cent qualifying for the weight standard, but the number of daughters concerned is entirely too small to be conclusive. The first cross of inbred lines gave a high percentage of daughters of satisfactory weight, but this result did not appear in the second generation produced by crossing inbred lines. Uniformly heavy weight was observed in the check daughters. It is evident, therefore, from these data that inbreeding did not greatly influence body weight at sexual maturity.

The percentage of daughters lacking winter pause did not change perceptibly under continued inbreeding. The first cross of inbred lines gave some improvement but the second generation was scarcely equal to the inbreds. A high variability in proportion of daughters free from winter pause occurred in the checks, probably due to environmental factors. In general, the proportion of females with winter pause does increase immediately with inbreeding and this increase is maintained by continued inbreeding.

High intensity showed neither an increase nor decrease under continued inbreeding. As compared with the check group and the first generation of inbred lines crossed, the inbred daughters were significantly lower in intensity. The data show that the first generation of inbred daughters exhibited very low intensity which was maintained through four generations.

There were no recognizable effects of inbreeding on the proportion of non-broody daughters produced, as shown by a comparison of inbreds with checks. This result might have been anticipated in a flock which is made up largely of non-broody individuals.

A cumulative effect of continued inbreeding on persistency was observed. The first generation inbred daughters showed about 53 per cent genetically highly persistent. In the third generation only 42.5 per cent were persistent. In the third generation only 12.5 per cent were persistent and in the fourth generation all daughters died before completing their laying year. Crossing inbred lines stimulated persistency to some extent.

Pullet-year hatching records were obtained on part of each generation of daughters, but the data are too inadequate to furnish much evidence on the relation between inbreeding and hatchability. They indicate, however, that inbreeding immediately lowers hatchability and the effect of inbreeding on hatchability appears to be cumulative. Crossing inbred lines resulted in a decided increase in the proportion of pullets hatching 85 per cent or more of fertile eggs.

Mean egg weight to January 1 tends to run heavier in the inbred daughters than in the checks. This difference is in part genetic and in part due to the greater age of inbreds when they lay their first egg. The first cross of inbred lines gave a still greater increase in egg size.

The first generation of inbred daughters gave a mean annual egg record of 172.29. The second generation showed about the same mean production, but the third generation fell to 154 eggs. In the fourth generation all pullets died before the end of their laying year. The check daughters sired by the same male as the inbred daughters showed a consistent increase in annual production as the experiment progressed, reaching a mean of about 228 eggs in 1931. Daughters from crossing inbred lines A and C gave higher annual egg records than any generation of inbred daughters. In this experiment inbreeding significantly reduced egg production in the first generation and in later generations.

The coefficients of variation in annual egg production show no reduction in variability that may be credited to inbreeding. No significant differences of variability between checks and inbreds is apparent. The apparent low variability from crossing the inbred lines in 1932 is not significantly lower than the other constants as judged by its probable error, due to small numbers of birds. There is, therefore, no evidence in these studies to indicate that inbreeding is effective in reducing variation in annual egg production.

The last column of Table 2 records the laying-house mortality of daughters for a 365-day period from date of housing. The mortality rate for inbred daughters had an upward trend during the experiment and all daughters of the last inbred generation died before the end of the year. Mortality rate was also excessive when the inbred lines were crossed. Inbreeding very definitely increased the mortality rate in the laying house in this experiment.

SUMMARY

1. Three inbred lines were established using the following standard in the selection of female breeders:

Sexual maturity—215 days or less.
Weight at first egg—5 pounds or over.
Winter pause—not over 4 days.
Winter clutch size—2.6 or over.
Broodiness—none during the pullet year.
Persistency—315 days or more.
Hatchability—85 per cent or more.
Egg weight—a minimum average of 52 grams to January 1.
Range mortality—not above 10 per cent in family.

Check females were selected each year from the general flock according to these standards and were mated to the inbred males. Female offspring from the most desirable families were retained and trapnested for a full year. One of the inbred lines failed to give any satisfactory breeding females in the third generation and was discontinued. The other two inbred lines were intercrossed in 1932 and 1933 and also bred as such.

2. Inbreeding increased range mortality, retarded sexual maturity, increased the percentage of birds with winter pause, reduced intensity, had no effect on broodiness, decreased persistency, reduced hatchability, increased winter egg weight, consistently reduced annual egg production without reducing its variability, and increased laying-house mortality.

3. Crossing inbred lines decreased range mortality in the first cross only, hastened sexual maturity, reduced the proportion of birds with pause, greatly increased intensity over that of the inbreds, improved persistency, increased hatchability, improved egg size, raised the annual egg production level above that of the inbreds but did not affect variability in egg production, and reduced the laying house mortality rate over that of the inbreds.

4. In no respect were the inbreds or inbreds crossed found to be superior to the general flock. Apparently nothing is to be gained from the standpoint of fecundity by inbreeding.

REFERENCES

Dunkerly, J. S. 1930. The effect of inbreeding. Proc. Fourth World's Poultry Cong. p. 46.

Dunn, L. C. 1923. Experiments on close inbreeding in fowls. Conn. Agr. Expt. Sta. Bul. 111.

Hays, F. A. 1924. Inbreeding the Rhode Island Red Fowl with special reference to winter egg production. Amer. Nat. 58:43-59.

Hays, F. A., and Ruby Sanborn. 1927. Intensity or rate of laying in relation to fecundity. Mass. Agr. Expt. Sta. Tech. Bul. 11.

Hays, F. A. 1929. Inbreeding in relation to egg production. Mass. Agr. Expt. Sta. Bul. 258.

Hays, F. A. 1933 a. Relation between body weight and age at sexual maturity. Poultry Sci. 12:23-25.

Hays, F. A. 1933 b. Characteristics of non-broody and intense broody lines of Rhode Island Reds. Mass. Agr. Expt. Sta. Bul. 301.

Jull, M. A. 1933. The effects on various characters of close inbreeding and of intercrossing inbred lines of White Leghorns. Jour. Heredity 24:93-101.

Publication of this Document Approved by Commission on Administration and Finance
3M-10-'34. No. 2621.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 313 October, 1934

Time Interval from First Egg to Standard Egg Weight in Rhode Island Red Pullets

By F. A. Hays

In breeding for egg size an important consideration is the time required by pullets to attain 24-ounce egg weight. This report is concerned with a number of factors that vitally influence this time interval.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

TIME INTERVAL FROM FIRST EGG TO STANDARD EGG WEIGHT IN RHODE ISLAND RED PULLETS

By F. A. Hays, Research Professor of Poultry Husbandry

INTRODUCTION

In a preliminary report Hays (1930) has shown that the time required by pullets to attain an egg weight of 57 grams, or about 24 ounces per dozen, varies widely and is influenced by such hereditary traits as age at sexual maturity, weight at sexual maturity, and intensity of laying. The ability to lay 57-gram eggs in a short time after sexual maturity was pointed out as being highly desirable economically.

This report is concerned with the relation between time required to attain standard (24 ounces per dozen) egg weight and various fecundity characters, as well as number of eggs laid in the winter season and during the pullet laying year. A study is also reported on fecundity traits and egg production of the birds that failed to attain standard egg weight the first year. The partial or net correlation has been determined between time required and the following independent variables: hatching date, age at sexual maturity, weight at sexual maturity, winter clutch size, winter pause duration, total days broody, and annual persistency; also the multiple correlation between these seven variables and time required. Greater variability in time required than can be ascribed to the seven variables studied may be assigned largely to hereditary factors that affect the time required to reach standard egg weight.

Data Available

Records are available on 409 birds that attained standard egg weight during the pullet laying year and 140 individuals that failed to attain standard egg weight. These birds were hatched from 1928 to 1932, and were all pedigreed Rhode Island Reds bred for high fecundity. The birds included in this study were all genetically early-maturing individuals, that is, beginning to lay at 215 days of age or younger. Each individual was considered as having attained standard egg weight when she had produced five successive eggs averaging 57 grams each.

EXPERIMENTAL RESULTS

Population Attaining Standard Egg Weight

A frequency distribution with respect to time to standard egg weight (the dependent variable) was made on the 409 individuals attaining standard egg weight. The X^2 test showed the lack of a normal distribution. When, however, 21 individuals that required less than 16 days to reach standard egg weight and 5 individuals that required more than 255 days were omitted, the distribution became sufficiently close to normal, giving a P value of .5143. It seemed desirable, therefore, to use for the correlation studies only the 383 birds that gave a normal distribution with respect to the dependent variable. Three independent variables showed essentially normal distribution; four—hatching date, winter pause, winter clutch, and persistency—did not. The partial or net coefficient of correlation differs from the simple correlation coefficient in that in the calculation of the former all other variables are held constant. For example, in calculating the net correlation between hatching date (2) and time to standard egg weight (1); age at first egg (3), weight at first egg (4), clutch size (5), pause duration (6), days broody (7), and persistency (8) are all made constant. In calculating simple correlations no allowance is made for variability in any of these characters.

Correlation Between Hatching Date and Time to Standard Egg Weight

In each of the five years covered by these studies, the birds were hatched in eight weekly hatches beginning about March 25 and ending about May 15. Yearly egg weight records are available only upon birds from the first three hatches. The simple correlation between hatching date and days from first egg to standard egg weight gave the following constants:

Number of birds	383
Mean hatching date (March 31)	1.8
Hatching date standard deviation	±.74
Mean time to standard egg weight, days	106.93
Time to standard egg weight standard deviation	±48.33
Coefficient of correlation	−.1111±.0340

The standard deviation in time to standard egg weight shows that the population was highly variable and suggests that this character must be influenced by a large number of factors that may be both hereditary and environmental.

The coefficient of correlation is negative and of sufficient magnitude to be barely significant according to the criterion of Wallace and Snedecor (1931). Its squared value, however, indicates that only about 1 per cent of the variation in time required is due to differences in hatching dates. The regression was found to be strictly linear, but the magnitude of the correlation coefficient in these limited data does not signify an intimate relationship.

The partial correlation coefficient between hatching date and time to standard egg weight was calculated, keeping age at first egg, weight at first egg, clutch size, pause days, broody days, and persistency constant. The value obtained was $r_{12.345678} = -.5323$, which indicates that hatching date does have an important influence upon the time required to reach standard egg weight, and that early hatching tends to increase the time necessary to attain standard egg weight.

Correlation Between Age at First Egg and Time to Standard Egg Weight

Early sexual maturity is known to be dominant to late sexual maturity. The dividing line between genetically early and genetically late pullets falls at about 215 in the experiment station flock. Unpublished data indicate no genetic difference with respect to age at sexual maturity between birds that begin to lay when less than 216 days of age even though the range may extend from 140 to

215 days. It is assumed, therefore, that such variability in age is due to environmental forces.

The simple correlation coefficient was calculated between age at first egg and time to standard egg weight using only genetically early-maturing birds. The constants obtained are as follows:

Number of birds	383
Mean age at first egg, days	178.76
Age at first egg standard deviation	±16.28
Mean time to standard egg weight, days	106.93
Time to standard egg weight standard deviation	±48.33
Coefficient of correlation	−.4174±.0285

The variability in age at first egg amounts to about 9 per cent in the population. As already stated, it is probable that this variability is due entirely to environmental causes.

The coefficient of correlation is negative and indicates that age differences play an important role in time to standard egg weight. The regression in this case is strictly linear.

The partial correlation between these two variables, when the other six variables are held constant is $r_{13.245678} = -.6419$, which clearly indicates that age at sexual maturity greatly influences the time to standard egg weight.

In the population studied, the mean average age at which standard egg weight was attained was found to be 285.21 days. This fact indicates that the Rhode Island Red pullets used in these studies tend to begin laying 24-ounce eggs at not far from ten months of age. It seems probable, according to the work of Waters (1931) with Leghorns and Brahmas, that this may also be the age when complete body growth is attained.

Correlation Between Weight at First Egg and Time to Standard Egg Weight

Each pullet was weighed on the day that she laid her first egg. Since there is a positive correlation between body weight and egg size, there may also be an association between weight at first pullet egg and time to standard egg weight. The correlation was calculated for the population being studied.

Number of birds	383
Mean weight at first egg, pounds	5.40
Weight at first egg standard deviation	±.56
Mean time to standard egg weight, days	106.93
Time to standard egg weight standard deviation	±48.33
Coefficient of correlation	−.2317±.0326

Body weight shows a variability of about 10 per cent, probably due largely to age differences, as Hays (1933) pointed out. The coefficient of correlation is negative and indicates by its value squared that about 5 per cent of the variability in time required is due to weight differences at first egg. The regression was essentially linear.

The partial correlation between weight at first egg and time to standard egg weight was −.3307. This constant indicates further that body weight at sexual maturity does not have a very great influence upon the time to standard egg weight.

Correlation Between Winter Clutch Size and Time to Standard Egg Weight

Mean winter clutch size is a very good measure of individual intensity. Furthermore, clutch size is governed by inheritance. Hays (1930) showed that the gene for highest intensity is linked with a gene for small egg size. It seems desirable, therefore, to determine by means of the correlation coefficient the relation between winter clutch size and time to standard egg weight. The constants calculated are as follows:

Number of birds	383
Mean winter clutch, eggs	3.49
Winter clutch standard deviation	±1.31
Mean time to standard egg weight, days	106.93
Time to standard egg weight standard deviation	±48.33
Coefficient of correlation	+.3001 ± .0314

The mean winter clutch indicates that the average individual carries the highest degree of inherited high intensity, yet the variability in intensity is very high.

The simple correlation shows a positive association between clutch size and time to standard egg weight. In other words, a little less than 10 per cent of the variability in time required may be accounted for through variable intensity. The regression is strictly linear.

Determination of the partial correlation between clutch size and time required gave the constant $r_{15.234678} = +.1609$, which indicates that less than 3 per cent of the variation in time required is directly traceable to intensity variations.

Correlation Between Winter Pause Duration and Time to Standard Egg Weight

Winter pause as used in these studies means the cessation of egg laying for four or more days between November 1 and March 1. In case there are several periods of non-production, these periods are added together to arrive at the pause duration. In the total population there were 146 birds showing no winter pause, and these are omitted in calculating the correlation between pause duration and time to standard egg weight.

Number of birds	237
Mean winter pause, days	27.07
Winter pause standard deviation	±20.78
Mean time to standard egg weight, days	106.04
Time to standard egg weight standard deviation	±46.66
Coefficient of correlation	+.1340 ± .0430

Duration of winter pause shows extreme variation in the population studied. This fact suggests that there must be many influences affecting pause duration. The data show further that the mean time interval for the pause birds is essentially identical with the time interval for the entire population.

The coefficient of correlation is positive but is not significant by Wallace and Snedecor's (1931, loc. cit.) criterion, and is of such small absolute magnitude as to be of little or no value as a guide in selection. The regression is strictly linear.

The net correlation between pause duration and time to standard egg weight was −.0582, showing that little, if any, association exists between pause duration and time interval to standard egg weight.

Correlation Between Total Days Broody and Time to Standard Egg Weight

There were only 49 individuals showing broodiness during the pullet laying year. The total days broody for each bird were determined by adding together the non-productive days associated with broody periods. The simple correlation between total days broody and time to standard egg weight was calculated, giving the following constants:

Number of birds	49
Mean days broody	31.42
Broody days standard deviation	±25.94
Mean time to standard egg weight, days	119.75
Time to standard egg weight standard deviation	±45.36
Coefficient of correlation	+.2679±.0894

Standard deviation in days broody shows striking variability. This is in agreement with the observation previously reported by Hays (1933) that degree of broodiness is inherited. Mean time to standard egg weight was slightly greater in the broody population than in the group that did not show broodiness the first year. The means are 119.73 and 104.90 respectively.

The correlation coefficient between days broody and time to standard egg weight is positive but not significant as judged by its probable error or by Wallace and Snedecor's criterion. The regression is strictly linear. From these limited data, the time required to standard egg weight does not appear to be associated with non-productive time due to broodiness.

The partial correlation between days broody and time to standard egg weight does, however, show a significant relationship. This constant was found to be +.4210, which indicates that about 18 per cent of the variation in time required is due to differences in degree of broodiness.

Correlation Between Annual Persistency and Time to Standard Egg Weight

Annual persistency records are available on 297 birds in the population studied. The remaining 86 individuals failed to complete their 365-day egg record, generally because of death or disease. Annual persistency was represented by the time from first pullet egg to a 30-day pause after March 1 or to the close of the 365-day laying year, if no 30-day pause occurred previously. Thus the maximum persistency was 365 days even though the bird may have continued to lay. Calculation of the correlation between annual persistency and time to standard egg weight gave the constants below:

Number of birds	297
Mean annual persistency, days	344.51
Annual persistency standard deviation	±33.44
Mean time to standard egg weight, days	107.34
Time to standard egg weight standard deviation	±48.21
Coefficient of correlation	−.0100±.0391

Annual persistency, like age at sexual maturity, showed a variability of about 9 per cent. The mean persistency of 344.51 days indicates that most of the birds were genetically highly persistent. The mean time to standard egg weight is almost identical in this group of 297 birds with the mean for the entire 383 birds previously considered.

No simple correlation exists between persistency and time to standard egg weight, and the regression is strictly linear.

A calculation of the net correlation between annual persistency and time to standard egg weight gives a constant of −.6241 which is highly significant. This constant indicates that about 39 per cent of the variation in time to standard egg weight is attributable to differences in persistency. This relation is largely obscured by the linkage relations between early sexual maturity and high persistency pointed out by Hays (1927).

Correlation Between Winter Egg Production and Time to Standard Egg Weight

Winter egg production includes all eggs laid from the first pullet egg in the fall or winter to March 1. The entire population of 383 birds was used to calculate the simple correlation between winter egg production and time to standard egg weight. The constants determined are as follows:

Number of birds	383
Mean winter production, eggs	100.71
Winter production standard deviation	±22.55
Mean time to standard egg weight, days	106.93
Time to standard egg weight standard deviation	±48.33
Coefficient of correlation	+.2599±.0321
Correlation ratio	.3373

A mean winter production of slightly over 100 eggs shows that the birds studied were very heavy winter layers. There is a variability of about 22 per cent which is rather high.

The regression of time required on winter production is not strictly linear so that the correlation ratio of .3373 really measures the association. Its value squared shows that about 11 per cent of the variation in time required is due to variation in winter production and that heavy winter layers tend to require a longer time interval to attain standard egg size.

Correlation Between Annual Production and Time to Standard Egg Weight

Egg size has been shown by a number of workers to be essentially independent of the number of eggs laid in a year. It is important to learn whether annual production affects the time interval to standard egg weight. Annual production used in this report represents the number of eggs laid by each individual in 365 days beginning with the first pullet egg. The correlation coefficient was calculated with the following constants:

Number of birds	297
Mean annual production, eggs	221.12
Annual production standard deviation	±37.87
Mean time to standard egg weight, days	107.34
Time to standard egg weight standard deviation	±48.21
Coefficient of correlation	+.0429±.0391
Correlation ratio	.3015

Annual egg production was rather high in the population studied, and the coefficient of variation was about 17 per cent. There was no difference in the average time interval to standard egg weight in the 297 birds that completed the year and the 86 birds that failed to complete the year.

The coefficient of correlation is positive and of no significance, but the regression is non-linear. The correlation ratio of .3015, therefore, expresses the association between annual production and time to standard egg weight. This constant shows that about 9 per cent of the variation in the time interval is due to variation in annual egg production. In other words, heavy producers tend to require more time to attain standard egg weight.

Correlation Between Mean Annual Egg Weight and Time to Standard Egg Weight

Mean annual egg weight was obtained for each bird by taking the average weight of all eggs laid from October 1 to September 30 each year. The simple correlation between annual egg weight and time to standard egg weight was calculated, with the constants shown below:

Number of birds	306
Mean annual egg weight, grams	55.45
Annual egg weight standard deviation	±2.59
Mean time to standard egg weight, days	108.15
Time to standard egg weight standard deviation	±48.41
Coefficient of correlation	−.6532±.0221

The data show that the mean annual egg weight was 55.45 grams, or the equivalent of 23.5 ounces to the dozen. Variability in egg weight was relatively slight, showing a coefficient of variation of about 4.6 per cent.

The coefficient of correlation between annual egg weight and time to standard egg weight was negative and of rather high magnitude. On the basis of its value squared, about 43 per cent of the variation in time required is due to variation in annual egg weight. The regression in this case was strictly linear. The data show that the time to standard egg weight very significantly affects the mean egg weight for the year; and if the mean egg weight for the year is to be 56.7 grams or 24 ounces to the dozen, pullets must reach standard egg weight in about 85 days, as calculated by the regression coefficient.

Multiple Correlation Between Time to Standard Egg Weight and Factors Affecting It

This study has demonstrated by means of the simple and the partial coefficients of correlation that the following factors affect the time to standard egg weight: hatching date, age at first egg, weight at first egg, winter clutch size, winter pause duration, total days broody, and annual persistency. With the possible exception of winter pause duration, all exert a significant effect on time to standard egg weight. These constants are placed together in Table 1.

Multiple correlation is resorted to in order to determine the combined effect of these seven factors (Nos. 2, 3, 4, 5, 6, 7, 8 in Table 1). Calculations show R = .7641. By squaring R, the value .5839 is obtained, which indicates that about 58 per cent of the variation may be accounted for by variation in the seven factors considered, leaving 42 per cent that appears to depend on undetermined hereditary factors. In view of this fact it seems probable that time to standard egg weight does depend upon hereditary factors and that poultry breeders can very likely make progress in breeding for large egg size by selecting only female breeders that attain standard egg weight in 75 days or less after the first pullet egg.

TABLE 1.--SIMPLE AND PARTIAL CORRELATION COEFFICIENTS BETWEEN TIME TO STANDARD EGG WEIGHT AND FACTORS AFFECTING IT

	Correlation Coefficients	
	Simple	*Net*
Correlation between Time to Standard Egg Weight (1) and		
2. Hatching date	−.1111 ± .0340	−.5323
3. Age at first egg, days	−.4174 ± .0285	−.6419
4. Weight at first egg, pounds	−.2317 ± .0326	−.3307
5. Winter clutch size, eggs	+.3001 ± .0314	+.1609
6. Winter pause, days	+.1340 ± .0430	−.0582
7. Broodiness, days	+.2679 ± .0894	+.4210
8. Persistency, days	−.0100 ± .0391	−.6241
9. Winter production, eggs	+.3373*	
10. Annual production, eggs	+.3015*	
11. Annual egg weight, grams	−.6532 ± .0221	

---

*Correlation Ratio.

Character of the Population Not Reaching Standard Egg Weight

During the five years covered by this study a significant proportion of the birds failed to attain standard egg weight during the first laying year. It seems desirable, therefore, to study this group in order to discover if possible some of the reasons why they continued to lay small eggs. Table 2 gives a series of means for the population failing to reach standard egg weight, together with the means for the population attaining standard egg weight.

TABLE 2.--A COMPARISON OF THE POPULATION FAILING TO REACH STANDARD EGG WEIGHT WITH THE POPULATION ATTAINING STANDARD EGG WEIGHT PULLET YEAR.

	Population Failing		*Population Attaining*	
	Number of Birds	*Mean*	*Number of Birds*	*Mean*
Age at first egg, days	140	175.50	383	178.76
Weight at first egg, pounds	140	5.10	383	5.40
Winter clutch size, eggs	140	3.66	383	3.49
Winter pause, days	83	26.09	237	27.07
Broodiness, days	17	40.21	49	31.42
Persistency, days	126	336.02	297	344.51
Winter production, eggs	140	106.71	383	100.71
Annual production, eggs	126	222.01	297	221.12
Annual egg weight, grams	131	49.91	306	55.45

The significance of differences in means recorded in Table 2 was determined by means of the probable error where the frequency distribution was essentially normal; in other cases by consistency.

There was no significant difference in age at sexual maturity between the two populations.

The two populations showed a significant difference in mean weight at first egg. It seems evident, therefore, that lack of body weight at sexual maturity is in part responsible for small egg size in the population that failed to reach standard egg weight.

Larger winter clutch size stood out in the small-egg population compared with the large-egg population. Extreme winter intensity accounted in part for the failure of one population to attain standard egg size.

The two groups of birds were identical in mean pause duration, and the small-egg group showed 59 per cent with winter pause compared with 62 per cent in the other group.

The small-egg group showed more intense broodiness, but the percentage of broody birds was essentially identical in the two populations.

In persistency, the small-egg group showed a significantly lower mean than the large-egg group. This fact appears to suggest that low persistency was in part responsible for small egg size.

The small-egg population showed slightly higher winter production and the same annual production as the large-egg group. The fact is therefore evident that number of eggs is not a factor governing egg size.

The group failing to reach standard egg weight gave a decidedly lower annual egg weight than the other group. The small-egg group gave an annual egg weight average of 21.1 ounces per dozen compared with 23.5 counces for the large-egg group.

SUMMARY

A study of the records of Rhode Island Red pullets hatched over a five-year period, where every egg was weighed from the trapnest, leads to the following deductions with respect to characters affecting the time interval between first pullet egg and standard egg weight or the failure to attain standard egg weight during the first laying year.

1. Early hatching greatly increased the time to standard egg weight.

2. Extreme early maturity within a genetically early-maturing population tended to greatly increase the time interval to standard egg weight.

3. Small body weight at first egg also increased the time interval but to a lesser extent than hatching date or age at sexual maturity.

4. Very high winter intensity was associated in some degree with a longer period to standard egg size.

5. Pause duration had little or no effect on the time interval.

6. Intense broodiness prolonged the period to standard egg weight.

7. High persistency very greatly reduced the time to standard egg weight.

8. High winter egg production slightly increased the time interval, but high annual production had no effect.

9. Annual egg weight was intimately negatively association with the time interval to standard egg weight.

10. The multiple correlation coefficient shows that about 58 per cent of the variation in time to standard egg weight was due to variation in the following seven variables: hatching date, age at first egg, weight at first egg, winter clutch size, winter pause, broodiness and persistency.

11. Probably about 42 per cent of the variation in the time interval to standard egg weight was due to unknown hereditary factors.

12. The birds failing to reach standard egg weight were handicapped by lack of body weight, extremely high intensity, intense broodiness, and lack of persistency.

13. In breeding practice to increase egg size, it seems advisable to select breeding females exclusively from those which attain standard weight egg in less than 75 days after the first pullet egg.

REFERENCES

Hays, F. A. 1927. The inheritance of persistency and its relation to fecundity. Proc. World's Poultry Congress, pp. 92-95.

Hays, F. A. 1930a. Increase in egg weight during the pullet laying year. Proc. Poultry Sci. Assoc., pp. 16-19.

Hays, F. A. 1930b. Linkage relations between genes for egg size and genes concerned in high fecundity in the domestic fowl. Proc. Fourth World's Poultry Congress, Sec. A, pp. 134-138.

Hays, F. A. 1933a. Relation between body weight and age at sexual maturity. Poultry Sci. 12:23-25.

Hays, F. A. 1933b. Characteristics of non-broody and intense broody lines of Rhode Island Reds. Mass. Agr. Expt. Sta. Bul. 301.

Wallace, H. A., and G. W. Snedecor. 1931. Correlation and machine calculation, p. 63. Iowa State College, Ames, Iowa.

Waters, N. F. 1931. Inheritance of body weight in domestic fowl. R. I. Agr. Expt. Sta. Bul. 228.

Publication of this Document Approved by Commission on Administration and Finance
3 M-10-'34. No. 2689.

AGRICULTURAL BRANCH LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 314 OCTOBER, 1934

Effect of Aging Treatment on the Bacterial Count of Ice Cream Mixes

By W. S. Mueller and R. L. France

This investigation was undertaken to determine whether the aging temperature of 68° F., considered desirable when gelatin is used in the manufacture of ice cream, has an unfavorable effect on the bacterial count of the product.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

EFFECT OF AGING TREATMENT ON THE BACTERIAL COUNT OF ICE CREAM MIXES

By W. S. Mueller, Assistant Research Professor of Dairy Industry and
R. L. France, Assistant Research Professor of Bacteriology

INTRODUCTION

It is a general belief in the ice cream industry that after the mix has been homogenized it must be cooled at once to a temperature of approximately 40° F. in order to avoid marked increases in bacterial growth during the aging period. However, to our knowledge, there is no experimental evidence to support this general assumption. No doubt aging an ice cream mix above 50° F. for 24 hours would result in a marked bacterial increase. Olson and Fay (1) reported that the aging, without agitation, of improperly cooled mix (65° F.) in cans in a cold room (38° F.), resulted in a marked increase in bacterial content in 24 hours.

The question remains as to whether or not an increase in bacteria would occur if a pasteurized mix were held for a relatively short time at a temperature above 50° F. The comparatively recent advocacy of a reduction of the aging period from 24 hours, or longer, to 2 to 4 hours makes it appear more feasible to use higher aging temperatures.

In previous publications (2, 3) by the senior author, it was shown that when an ice cream mix contained gelatin the efficiency of this ingredient was increased by aging the ice cream mix for 4 hours at 68° F., regardless of whether or not this was followed by aging at a lower temperature. The efficiency of the gelatin was increased to such an extent that the gelatin could be reduced approximately one-fourth without impairing the quality of the finished product. Also, a limited number of trials showed that aging a pasteurized mix at 68° F. for 2, 4, and 6 hours had no apparent effect on the bacterial growth, pH, or titratable acidity, which would be of any commercial significance.

The purpose of the work herein reported was: to check the results previously reported concerning the effect on the bacterial count of aging ice cream mixes at 68° F. for 6 hours; to study the effect on the bacterial count of aging ice cream mixes at 68° F. for 6 hours, followed by aging at 38° F. for 18 hours; to determine at what time significant increases in bacterial count occur in ice cream mixes held at 68° F.

PLAN OF EXPERIMENT

The general plan of this study was to subject both pasteurized and raw ice cream mixes to the following aging treatments, and compare the total bacterial counts of the mixes so treated:

(1) Unaged.
(2) Held 6 hours at 38° F.
(3) Held 6 hours at 68° F.
(4) Held 24 hours at 38° F.
(5) Held 6 hours at 68° F., plus 18 hours at 38° F.

Also, pasteurized and raw mixes were held at 68° F. for varying periods of time in order to determine when the bacterial counts start to increase. Although raw mixes are rarely used in commercial practice, they were included in this experiment for comparison with pasteurized mixes, in order to obtain if possible some information as to why the bacterial content of the pasteurized mixes does not increase markedly with holding at 68° F. for 6 hours.

Experimental Methods

Preparation of the pasteurized mixes. Most of the ice cream mixes were prepared and processed in the college creamery. A few raw and processed mixes were obtained from nearby commercial ice cream plants, the raw mixes being subsequently pasteurized at the college creamery. The mixes represented a variety in formulas, ingredients, and size of batch. All of the ingredients, with the exception of the flavoring material, were mixed, pasteurized, and homogenized together.

Pasteurization. The ice cream mixes were pasteurized in most instances at 145° to 150° F. for 30 minutes. In some instances other combinations of temperature and time were used in order to secure higher initial bacterial counts.

Homogenization. Most of the mixes were homogenized at 2500 pounds pressure per square inch, at the temperature of pasteurization. In most instances the homogenizer was thoroughly washed and sterilized before being used. In some instances, in order to secure higher initial bacterial counts, the homogenizer was not thoroughly cleaned.

Cooling and Aging. Immediately after homogenization the mixes were cooled to their respective aging temperatures either over the surface cooler, or in sterile flasks set in cold brine. Aging was done in sterile flasks which were placed in either a thermostatically controlled water bath or a thermostatically controlled temperature box. Samples from these flasks were plated at various times during the aging period.

Preparation of the unpasteurized mixes. The mixes used represented a variety in formulas, ingredients, and size of batch. All of the ingredients, with the exception of the flavoring material were mixed, heated to approximately 100° F., and immediately homogenized at 2500 pounds pressure per square inch. After homogenization the unpasteurized mixes were treated in the same manner as the pasteurized mixes.

Bacteriological methods. Samples for the bacteriological analyses were weighed, and the number of bacteria per gram of sample were determined by the agar plate count method recommended by the American Public Health Association (4).

EXPERIMENTAL RESULTS

Effect of Aging Treatment on the Bacterial Count of Pasteurized Ice Cream Mixes

Table 1 gives the original data obtained when pasteurized ice cream mixes were subjected to various aging treatments. It will be observed that the bacterial counts of the raw mixes covered a wide range, the highest being 58,000,000 per gram and the lowest 1,000. When the counts before and after pasteurization

Table 1. Effect of Aging Treatment on the Bacterial Count of Pasteurized Ice Cream Mixes.

Mix No.	Bacterial Count of Mixes before Pasteurization	Bacterial Count of Pasteurized Mixes				
		Before Aging	Held 6 Hours at 38° F.	Held 6 Hours at 68° F.	Held 24 Hours at 38° F.	Held 6 Hours at 68° F. plus 18 Hours at 38° F.
1	2,100	60,000			75,000	70,000
2		1,400	2,300	2,000	4,000	3.000
3	11,000	8,000	6,200	7,000	9,000	8,000
4	22,000	2,000	3,200	2,500	2,400	2,100
5	16,000	5,000	3,000	3.200	3,200	3,000
6	8,500	5,400			2,500	3,100
7	9,000	4,000			2,100	1,800
8	8,000	6,000			3,500	2,700
9	8,000	1,200			700	1,000
10	240,000	5,100	4,700	5,300	5,000	15,000
11	1,090,000	18,000			12,000	14,000
12	13,800	11,000	12,700	13,100	12,800	12,400
13	58,500,000	17,600	17,100	16,800	12,100	11,400
14	10,000	27,000	23,200	38,000	23,000	24,000
15	23,000	10,000	15,400	14,700	4,900	7,600
16	620,000	9,800	3,000	9,400	4,700	17,900
17	300,000	44,000	10,600	26,000	45,000	29,000
18	55,000	4,500	3,300	4,000	7,500	4,500
19	5,400	1,300	1,400	1,700		
20	150,000	750		650	800	
21	29,600	9,250		10,400	6,650	
22	10,400	1,750	1,850	1,950	1,600	1,600
23	143,500	24,500	32,000	42,000	24,000	24,000
24	3,500	3,150	2,750	1,950	1,650	2,050
25	1,000	650	500	950	1,250	1,400
26	120,000	2,300	2,000	1,600	1,550	1,450
27	11,000,000	90,000	97,000	98,000	92,000	91,000
28	1,500,000	240,000	170,000	181,500	165,000	177,000
29	16,000,000	4,000	3,000	5,000	4,100	6,500
30	1,700,000	39,000	110,000	53,000	47,000	65,000
31		50,000	42,000	51,400		
32		10,500	10,000	12,000		
33		10,300	8,900	10,000		
34		15,300	10,800	10,900		
35		1,170,000	1,015,000	1,110,000		
36		4,100	3,700	3,700		

are compared, the expected decrease is observed. However, in a few instances the pasteurized mix had a higher count than the raw mix, due, no doubt, to recontamination of the mix from the homogenizer.

Table 2 contains a summary of the data given in Table 1. The 36 mixes are classified on the basis of initial bacterial count, and comparisons of final bacterial count made on the bases stated in headings I, II, and III of the table. Naturally there is some error inherent in the technic employed; for this reason all counts falling within 15 per cent of the control count for the same sample are considered "the same," counts more than 15 per cent above the control count are considered "higher," and counts more than 15 per cent below the control count are considered "lower." This procedure for interpreting the data was followed throughout the experiment. The "initial count" refers to the count obtained on the unaged mix immediately after homogenization. It will be noted that the total number of trials for each separate comparison does not equal 36. This was due, not to the omission of data, but to the fact that platings were not made of every sample each time.

In comparison I, slightly more than one-third of the cases showed a higher bacterial count; in comparison II, one-third of the cases were higher; while in comparison III, slightly less than one-third of the cases were higher. When analyzing the cases which showed an increase, it was found that in no instance did the total count go above the maximum bacterial count tolerated by those states which have a bacterial standard for ice cream. The results given in Tables 1 and 2 show that a pasteurized ice cream mix may be aged for 6 hours at 68° F., whether followed by a low-temperature aging period or not, without an increase in bacteria which would be of any commercial significance.

TABLE 2.--EFFECT OF AGING TREATMENT ON THE BACTERIAL COUNT OF ICE CREAM MIXES.

Summary of Data on Pasteurized Mixes

Classification of Mixes by Initial Bacterial Count	COMPARISON I. Mixes aged 6 hours at 68° F. Controls aged 6 hours at 38° F.			COMPARISON II. Mixes aged 6 hours at 68° F. plus 18 hours at 38°. Controls aged 24 hours at 38°			COMPARISON III. Mixes aged 6 hours at 68° F. plus 18 hours at 38°. Controls aged 6 hours at 68°.		
	Higher	Lower	Same	Higher	Lower	Same	Higher	Lower	Same
2,500 or less	2	2	2	1	1	4	2	2	1
2,501— 5,000	2	1	2	2	1	2	1	0	3
5,001—10,000	1	0	3	4	1	1	2	1	1
10,001—50,000	5	1	4	2	1	4	1	3	2
Over 50,000	0	0	3	0	0	3	0	0	2
TOTALS	10	4	14	9	4	14	6	6	9

Summary of Data on Unpasteurized Mixes

TOTALS	5	0	0	5	0	0	3	0	2

The Effect of Prolonged Aging at 68° F. on the Bacterial Count of a Pasteurized Ice Cream Mix

The data in the preceding experiment showed that a pasteurized ice cream mix may be held for 6 hours at 68° F. with no significant increase in bacterial count. The present experiment was undertaken to determine how long the mix can be held at 68° F. before the bacterial count begins to increase. Pasteurized mixes were held at 68° F. and platings made at various intervals up to 24 hours, with results shown in Table 3. Bacterial counts when the mixes were aged at 38° F. are included for comparison. The unaged mixes served as controls.

TABLE 3.--EFFECT OF LENGTH OF AGING PERIOD ON PASTEURIZED MIXES.

Mix No.	Bacterial Count of Mixes before Pasteurization	Bacterial Count of Pasteurized Mixes									
		Before Aging	Aged at 68° F.						Aged at 38° F.		
			2 Hours	4 Hours	6 Hours	10 Hours	12 Hours	24 Hours	6 Hours	12 Hours	24 Hours
1		50,000	52,000	50,500	51,400				42,000		
2		10,500	10,000	11,500	12,000				10,000		
3		10,300	8,300	11,700	10,000				8,900		
4		15,300	18,700	17,000	10,900				10,800		
5		1,170,000	1,220,000	1,516,000	1,110,000				1,015,000		
6		4,100			3,700				3,700		
7	5,400	1,300	1,400	1,500	1,700	1,500	2,100			1,400	
8	150,000	750			650	750		13,000			800
9	29,600	9,250			10,400		10,650	196,000			6,650
10	10,400	1,750			1,950	1,600	1,450	155,000			1,600
11	143,500	24,500			42,000	34,000	102,500	4,000,000			24,000
12	3,500	3,150			1,950	3,500		55,000			1,650
13	1,000	650			950		5,700	470,000			1,250
14	120,000	2,300			1,600		6,500	40,000			1,550
15	11,000,000	90,000			98,000		138,000	94,500			92,000
16	1,500,000	240,000			181,500		267,000	1,250,000			165,000
17	16,000,000	4,000			5,000	7,000	7,000	60,000			4,100
18	1,700,000	39,000			53,000	79,000	105,000	2,400,000			47,000

No definite increase in bacterial count occurred up to 10 hours. Of the mixes held for 10 hours, 3 showed an increase and 4 were the same. After 12 hours, the number of organisms increased in 7 cases, decreased in 1 case, and remained the same in 2 cases. In all but one case the bacterial count showed a marked increase after 24 hours at 68° F. The results obtained in this experiment indicate that when a pasteurized mix is held at 68° F., a definite increase in bacterial count does not occur until after the tenth hour.

Effect of Aging Treatment on the Bacterial Count of Unpasteurized Ice Cream Mixes

Although the majority of commercial ice cream mixes are pasteurized, unpasteurized mixes were used in this experiment for comparison. The data are given in Table 4 and summarized in Table 2. Both high and low count mixes were used.

TABLE 4.--EFFECT OF AGING TREATMENT ON THE BACTERIAL COUNT OF UNPASTEURIZED MIXES.

Before Aging*	Held 6 hours at 38° F.	Held 6 hours at 68° F.	Held 12 hours at 68° F.	Held 24 hours at 68° F.	Held 24 hours at 38° F.	Held 6 hours at 68° F. plus 18 hours at 38° F.
14,000	13,500	21,200	52,000	3,500,000	16,300	24,000
1,400,000	1,500,000	7,000,000	50,000,000	470,000,000	1,460,000	12,000,000
270,000	310,000	400,000	3,800,000	50,000,000	336,000	550,000
16,000,000	15,600,000	29,000,000	51,000,000	84,000,000	25,000,000	29,000,000
1,700,000	2,100,000	9,000,000	38,000,000	123,000,000	1,700,000	22,000,000

*After Homogenization.

Table 4 shows that when a raw mix is held at 68° F., a definite increase occurs after 6 hours; and this increase, as would be expected, becomes more marked after 12 and 24 hours. The summary in Table 2 indicates clearly that the bacterial counts of raw mixes aged at 68° F., whether followed by low-temperature aging or not, are definitely higher than the bacterial counts of the control mixes aged at 38° F.

GENERAL DISCUSSION

It has been generally assumed that if an ice cream mix is not cooled immediately after homogenization to approximately 40° F., substantial increases in bacteria will occur. In a previous study (3) as well as in this study, it has been shown that pasteurized ice cream mixes may be aged for 6 hours at 68° F. with no marked increase in bacterial count. In all probability the effect of temperature shock on the organisms and also the type of organisms surviving pasteurization are chiefly responsible for the absence of any marked increase in bacteria when a pasteurized mix is held at 68° F. for 6 hours or even for 10 hours.

Throughout this experiment most of the mixes were handled so as to prevent recontamination after pasteurization. In some preliminary experiments, however, where pasteurized mixes were recontaminated with lactic acid organisms after cooling to 68° F., it was found that the bacterial count increased as much as 600 per cent when these mixes were held for 6 hours at 68° F., as compared with identical mixes held for 6 hours at 38° F. Therefore, in all probability, a pasteurized mix recontaminated after cooling would show a marked increase in bacteria after being held 6 hours at 68° F. This point should not be considered an objection to short-time aging at 68° F., as it is not good practice in ice cream making to permit recontamination of the mix after pasteurization.

In a previous study (3) it was shown that by aging ice cream mixes for 4 hours at 68° F., the efficiency of the gelatin was increased enough so that the gelatin content could be reduced one-fourth without impairing the quality of the ice cream. Since no objectionable increase in bacteria occurs when the mix is held at 68° F. for 6 hours, or in some cases for 10 hours, the ice cream manufacturer can increase the efficiency of the gelatin in the mix by aging at 68° F. and yet have at least 2 hours as a margin of safety from a detrimental increase in bacteria.

SUMMARY

1. The aging of pasteurized ice cream mixes for 6 hours at 68° F., whether followed by aging for 18 hours at 38° F. or not, did not result in a significant increase in the number of bacteria present.
2. When a pasteurized ice cream mix was aged for 24 hours at 68° F., a definite increase in the bacterial count did not occur until after the tenth hour.
3. The aging of an unpasteurized mix for 6 hours at 68° F., whether followed by aging for 18 hours at 38° F. or not, resulted in a material increase in the number of bacteria present.
4. The aging of a mix for 24 hours at 38° F. did not result in a material increase in the number of bacteria present, which agrees with previous findings.

LITERATURE CITED

(1) Olson, N. E., and Fay, A. C. 1925. The bacterial content of ice cream. Jour. Dairy Sci. 8 (No. 5):415-444.

(2) Mueller, W. S. 1933. Aging effects on gelatin dispersions. Indus. and Engin. Chem. 25 (No. 6):707.

(3) Mueller, W. S., and Frandsen, J. H. 1933. Higher aging temperatures in the manufacture of ice cream. Mass. Agr. Expt. Sta. Bul. 302.

(4) Standard methods of milk analysis. 6th edition, 1934. Published by the American Public Health Association.

Publication of this Document Approved by Commission on Administration and Finance
5M-10-'34. No. 2661.

AGRICULTURAL [illegible] LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 315 MARCH 1935

Annual Report

For the Fiscal Year Ending November 30, 1934

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Trustee Committee on Experiment Station

	Term Expires
BUTTRICK, DAVID H., Arlington, *Chairman*	1939
CHANDLER, JOHN, Sterling Junction	1935
RUSSELL, HOWARD S., Waltham	1936
FROST, HAROLD L., Arlington	1938
MALCOLM, DAVID J., Charlemont	1939
WHITMORE, PHILIP F., Sunderland	1941

Experiment Station Staff, December 1934

HUGH P. BAKER, President of the College

SIEVERS, FRED J., Director
GASKILL, EDWIN F., Assistant to the Director
KENNEY, FRED C., Treasurer
CHURCH, LUCIA G., Secretary

BEAUMONT, ARTHUR B., Agronomy
*BOURNE, ARTHUR I., Entomology
*BRADLEY, LEON A., Bacteriology
*CANCE, ALEXANDER E., Agricultural Economics
*CHENOWETH, WALTER W., Horticultural Manufactures
DORAN, WILLIAM L., Botany
*EISENMENGER, WALTER S., Agronomy
FELLERS, CARL R., Horticultural Manufactures
*FRANDSEN, JULIUS H., Dairy Industry
†*FRANKLIN, HENRY J., Cranberries
*GASKILL, EDWIN F., Station Service
GIBBS, CHARLES S., Veterinary Science
*GRAHAM, JOHN C., Poultry Husbandry
*GUNNESS, CHRISTIAN I., Agricultural Engineering and Meteorology
*HASKINS, HENRI D., Fertilizer Law
HAYS, FRANK A., Poultry Husbandry
HOLLAND, EDWARD B., Chemistry
‡*KOON, RAY M., Vegetable Gardening
*LENTZ, JOHN B., Veterinary Science
LINDSEY, ADRIAN H., Agricultural Economics
LINDSEY, JOSEPH B., Chemistry (Professor Emeritus)
MORSE, FRED W., Chemistry
*OSMUN, A. VINCENT, Botany
*RICE, VICTOR A., Animal Husbandry
*RITCHIE, WALTER S., Chemistry
*SEARS, FRED C., Pomology
SHAW, JACOB K., Pomology
*SMITH, PHILIP H., Feed, Dairy and Seed Laws
*THAYER, CLARK L., Floriculture
VAN METER, RALPH A., Pomology
VAN ROEKEL, HENRY, Veterinary Science
*WOOD, BASIL B., Library
KUZMESKI, JOHN W., Fertilizer Law
McLAUGHLIN, FREDERICK A., Seed Law
*MIGHELL, RONALD L., Farm Management
MUELLER, WILLIAM S., Dairy Industry
PRAY, F. CIVILLE, Chemistry
ROZMAN, DAVID, Agricultural Economics
SPELMAN, ALBERT F., Feed Law
‡WHITCOMB, WARREN D., Entomology
‡WHITE, HAROLD E., Floriculture
‡YOUNG, ROBERT E., Vegetable Gardening
*———, Home Economics Research

ARCHIBALD, JOHN G., Animal Husbandry
BAILEY, JOHN S., Pomology
‖BERGMAN, HERBERT F., Cranberries
BULLIS, KENNETH L., Veterinary Science
DeROSE, H. ROBERT, Fertilizer Law
‡DEMPSEY, PAUL W., Horticulture
*FELTON, F. ETHEL, Editor
FLINT, OLIVER S., Veterinary Science
FRANCE, RALPH L., Bacteriology
FULLER, JAMES E., Bacteriology
‡GUBA, EMIL F., Botany
JEFFERSON, LORIAN P., Agricultural Economics
JONES, CARLETON P., Chemistry
JONES, LINUS H., Botany
‖KIGHTLINGER, CLIFFORD V., Tobacco-Disease Investigations
ALLEN, HARRY L., Feed, Fertilizer and Dairy Laws
BALL, ALYN S., Botany
BENNETT, EMMETT, Chemistry
BUCK, ROBERT E., Horticultural Manufactures
CLAGUE, JOHN A., Horticultural Manufactures
CLARKE, MIRIAM K., Veterinary Science
DONLEY, J. ELIZABETH, Agricultural Economics
‡DONNELLY, EDWARD B., Floriculture
ESSELEN, WILLIAM E., JR., Horticultural Manufactures
HOWARD, JAMES T., Feed, Fertilizer and Dairy Laws
HUGHES, MARY C., Pomology
ISHAM, PAUL D., Horticultural Manufactures
MERRIAM, OREANA A., Home Economics Research
MINER, GLADYS I., Botany
O'DONNELL, MARGARET H., Administration
ONSDORFF, THOMAS, Horticultural Manufactures
PARKINSON, LEONARD R., Station Service
ROBERTSON, DORIS W., Farm Management
SANBORN, RUBY, Poultry Husbandry
SHERBURNE, RUTH E., Agricultural Economics
SNELL, MOSES E., Agronomy
‖TRURAN, WALTON E., Cranberries
WATSON, VERNON K., Horticultural Manufactures
‡WILSON, HAROLD A., Vegetable Gardening
ZIMNOSKI, FELICIA, Veterinary Science
———, Seed Law

---

*In charge †At East Wareham ‡At Waltham ‖With U. S. D. A.

CONTENTS

Page

Introduction 4

Department Reports:

- Agricultural Economics 5
- Agricultural Engineering 8
- Agronomy 9
- Animal Husbandry 18
- Bacteriology 21
- Botany 23
- Chemistry 27
- The Cranberry Station 31
- Dairy Industry 35
- Entomology 38
- Farm Management 52
- Feed Control Service 54
- Fertilizer Control Service 56
- Floriculture 58
- Horticultural Manufactures 59
- Olericulture 62
- Pomology 65
- Poultry Husbandry 74
- Veterinary Science 75
- Waltham Field Station 79

Cooperative Investigations:

- Cranberry 32
- Tobacco 16

Publications 81

ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION--1934

INTRODUCTION

F. J. Sievers, Director

When the last annual report was in preparation, there was a genuine feeling on the part of a considerable portion of our citizenship that research in general and especially in the field of agriculture was so far in advance of its application to practice that a partial holiday in the promotion of further investigations might be justified. The pronounced interest in balancing budgets expressed itself very forcefully in a definite attempt to curtail Federal and also State support to the experiment stations. Although recommendations for curtailment did not prevail, they had the effect of subjecting the entire experiment station service to very close scrutiny. Since then developments in attempts to solve the problems of depression have been numerous and rapid, with the result that those administrative leaders of national, industrial, and political affairs who are giving constructive thought to this subject are becoming convinced that a sound solution requires a type of basic information that is not now available. The acquirement of such basic information is naturally dependent upon research, and nothing could be more treacherous than to be misled at this time by so-called facts coming from a prejudiced source. In other words it is becoming recognized that the solution of the profound social and economic problems confronting the country requires research emanating from a source free from bias.

While individual experiment station workers may have their prejudices, there is certainly no research agency in this country that should be as free from selfish, commercial, or political influence as the several experiment stations as now organized in every state in the Union. It is, therefore, reasonable to assume not only that service in social and economic adjustment is an obligation of the experiment stations, but that there will be a demand for these agencies to supply basic information in this field similar to the contribution that is being made to science in general and agriculture in particular.

To make sure that we shall not be found wanting, an effort is being made to reshape our program so that special consideration may be given to these significant problems with which our entire consuming public is concerned. Such modification in our program not only demands the best intellect available in the organization, but also justifies a degree of enthusiasm for service that can not fail to express itself in enlarged output.

Another matter in experiment station organization deserving preferred consideration is the encouragement of cooperation among members of the staff engaged in different but related services. In recent years so much emphasis has been placed on the importance of specialization that the old-time agriculturist or horticulturist who was conversant with the entire field of activities included under these designations has practically disappeared. He has been displaced in large part by the physiologist, geneticist, threpsologist, pathologist, etc., all highly specialized in their training and interest. While this has made for a pronounced advance in efficiency and in scientific quality of research, there is a danger that if encouraged beyond reasonable limits it may result in the loss of a sympathetic interest in agriculture as an industry or in a lack of ready responsiveness to the problems of the general consuming public. In order to supplement the efficiency of specialists, who due to the nature of their work have a tendency to become further and further isolated, some means should be provided that will make the need for cooperation so evident that more intimate contact among investigators will become automatic.

With this in mind the experiment station is setting up a central nutrition laboratory made possible through the remodeling and reconstruction of the Hatch barn formerly used for investigations in animal feeding. This laboratory when completed should offer facilities for investigational work in the entire field of nutrition both human and animal, and in this respect serve all of the departments having a natural interest in feeding problems. The proposed organization will influence the research of the following departments:

Agronomy
Animal Husbandry
Bacteriology
Chemistry
Dairy Industry
Feed Control Service
Home Economics
Horticultural Manufactures
Poultry Industry

In line with this new development one project is already organized where the departments of Agronomy, Chemistry, and Home Economics are cooperating in an effort to influence the nutritional composition of some of our natural plant products in the hope of supplying a partial solution for the problems of nutritional deficiency recognized but unsolved by the medical practitioner and dietitian. It is conceivable that similar projects may be developed in which animal products and processed foods may be given this same type of consideration. Whatever the development may be, it is quite evident that the soundest recommendations in such involved fields of research will be available only after the unprejudiced analysis and consultations possible under a liberal and flexible cooperative policy.

It would seem, therefore, that only a limited imagination is required to arrive at the realization that research in agriculture, instead of being credited with having fulfilled its mission, should be saddled with the solution of many of the profound and intricate problems that are developing and will continue to develop in a highly organized and much standardized society.

DEPARTMENT OF AGRICULTURAL ECONOMICS

Alexander E. Cance in Charge

Decentralization of Industry and Part-Time Farming in Massachusetts. (David Rozman.) The field work in connection with this project has been in the main completed and the data are being tabulated and analyzed for publication.

To determine the extent to which the location of industrial plants in smaller communities of Massachusetts has been productive of the combined use of labor in industry and agriculture, a general survey was made of all the industries of the State operating in the towns and cities of less than 10,000 population. Information was also obtained on the regularity of employment and seasonal character of operation in different industries as it might affect the practice of agriculture by employees.

In the towns of Charlton and Winchendon a detailed study was made of the standard of living and comparative advantages for homogeneous groups of employees engaged in part-time farming and those outside of it.

Marketing of Milk and Cream in Secondary Markets of Massachusetts. (David Rozman.) A detailed survey has been made of both demand and supply of milk and cream in all the important secondary markets of the State, including 27 cities. Information was collected from every dealer and producer-distributor operating in the surveyed territory as to the daily receipts and sales of milk and cream, retail and wholesale prices for different grades, milk purchase plans in relation to producers, number and location of producers, and quality of product. All the data obtained in this survey were tabulated and summarized, and are now being used as a practical working basis in some operations of the State Milk Control Board.

Competitive Factors Influencing the Supply of Market Milk and Cream. (A. H. Lindsey and A. E. Cance.) A mimeographed report has been published of the sources and consumption of fluid milk in 27 secondary markets in Massachusetts.

Under this project a historical study of milk sources and quality was made in the Lowell market. Complete records were available for a 10-year period. There have been many changes in areas which furnish milk to Lowell. These, however, may be largely accounted for by changes in supply made by large dealers. Quality, as measured by bacterial count, sediment tests, and percentage of fat and solids, has constantly improved throughout the 10-year period.

Preliminary investigation, based on 25,000 samples over a 10-year period, indicates that the seasonality of fat and solids content of milk is not related to the quantity of milk produced by cows as affected by pasture and feed conditions. The low point in fat content is normally in August and not in May or June as commonly supposed. Fat and solids content appears to be more closely related to temperature than to pasture conditions or quantity of milk produced. The low point for solids may or may not coincide with the low point for fat. It is very important that producers know the true seasonal curves for fat and solids.

Further work remains to be done to establish an adequate basis for any conclusions to be made.

Sources and Uses of Credit in Massachusetts. (A. H. Lindsey.) The primary purpose of this study is to secure dependable data for the Farm Credit Administrators and for extension workers, so that the present credit facilities can be made more adequate, useful, and convenient. The survey was planned to determine the credit needs of different type-of-farming areas. Records for the Connecticut Valley are adequate, but a further study of dairy, poultry, and market garden areas in the eastern part of the State remains to be made.

A summary of the data gathered follows:

1. Of the 340 farmers included in the survey, only 5 were tenants; the remainder owned their own farms.
2. In the Connecticut Valley area the farmers who were less than 40 years of age borrowed, on the average, one and a third times the amount of short-term credit per farmer borrowed by farmers who were 60 or more years of age.
3. The average amount of short-term credit borrowed per farmer included in the survey was $774. The average amount borrowed per farmer who obtained short-term credit was $1,315.
4. Sixty percent of bank credit was due on demand, and 17½ percent due in six months.
5. Not quite one-half of the bank credit outstanding August 1934 had been renewed more than twice.
6. About 70 percent of the farmers who owned their farms owed mortgage credit.

7 Of the first mortgage credit, 42.9 percent bore 6 percent interest; the remaining 57.1 percent bore lower rates, 27.6 per cent of which was at 5 percent.

8. Seventy-eight percent of the first mortgage credit was payable on demand.

9. A little over half of the first mortgage credit was supplied by commercial banks.

10. The Federal Land Bank loaned the largest amounts per farmer, distant commercial banks the second largest, and Smith Charities the smallest.

11. Among the farmers of the Connecticut Valley area were 26 men who still had tobacco stored, and hence had no cash income from that source. Their average total indebtedness was $7,161, while the average total indebtedness for the entire group was $5,475.

A Study of Performance of Different Varieties of Apples and Market Value of Product. (Lorian P. Jefferson.) This project, held in abeyance for a time, is being reorganized with the intention of getting data from various growers throughout the State, not merely from growers in one section, as at first planned. It is also the intention to extend the period for which the data are to be secured to ten years.

Some of the growers who gave data earlier will be included in the study as now planned. Some it will be necessary to omit for one reason or another. Each of the county agents, except in the southeastern counties, has furnished a list of growers who probably have records of crops and sales from which desired information can be secured. In Berkshire County not one grower is known to have records for ten years. Of course, few apples are grown in commercial orchards in the southern part of the State.

The Changing Methods of Wholesale Distribution of Perishables. (Lorian P. Jefferson.) The motor truck has come to be a great factor in the marketing of fruits and vegetables, although the total volume which reaches the market by this means is not known. The effects are both good and bad: Good, in that fruit so shipped usually reaches the market in better condition than that shipped by rail; and bad, because of the effect on the market. The testimony of dealers indicates no pre-announcement of the arrival of truck-borne fruit, which leaves the market without protection against unknown receipts. A movement on foot throughout the large markets asks that information regarding volume, character and time of arrival of trucks be required.

More than one organization has expressed the opinion that the traveling jobbers should be placed under Federal control, in order that they may be as uniformly controlled as is their competitor, the railroad. Nothing has been done about this matter as yet, but there is a strong sentiment in favor of it among various people.

There is a general feeling in the market that something should be done about stopping wastes of foods. Studies are being made into the best means of avoiding the various wastes that are common in our present handling of perishable foods. Improved refrigeration, better freight service, and better loading practices have reduced transportation losses. Some of these depend upon proper chemical conditions, some upon economics and proper loading, all of which are being studied.

Market terminals are becoming more and more important. The one in Boston, conducted by the New York, New Haven and Hartford railroad, is handling an increasing proportion of perishable products entering the city. Beginning in April 1927, the terminal has handled much more than the stipulated volume of these products and has now reached a total well above that amount. The cars are handled quickly, and the products are distributed as rapidly as possible and reach the retailer when fresh.

There are market terminals in twelve of our large markets, ranging in size from Atlanta, Georgia, to Washington, D. C. Some of these are owned by railroads and produce trade, and operated by the railroads and (or) a Terminal Company or market company.

In Boston, the buyers at the market terminal include several groups: (1) wholesalers from Boston and from other markets from Portland to New Bedford; (2) retailers who do a volume of business which warrants buying the units specified; (3) chain store systems; (4) regular jobbers; and (5) traveling jobbers whose business is sufficient so they can buy the required quantities.

DEPARTMENT OF AGRICULTURAL ENGINEERING

C. I. Gunness in Charge

Investigation of Apple Storages. (C. I. Gunness in cooperation with the Department of Pomology.) The study on holding apples at 45° F. during the time of loading and for a short period thereafter before reducing to 32° has been continued. The results are being reported by the Department of Pomology.

The test on the effect of humidity on the keeping of apples was continued. McIntosh were stored under three different humidities and two sets of temperature conditions, with the following results:

Temperature (°F.)	Humidity (Percent)	Percentage Loss in Weight by Feb. 15
*34	90	1.6
	80	3.3
	70	4.0
**45 to 35	90	2.8
	80	5.6
	70	6.7

*Throughout the season.

**Started at 45° Oct. 1 and gradually reduced to 35° by Feb. 1.

None of the apples held at 34° had shriveled badly, although those kept at the lower humidity showed slight shriveling. Those kept at the higher temperature showed shriveling at all humidities although much more noticeably at the low humidities. It is felt that the test on humidity at the high temperature is not significant as the high temperature was maintained too long for proper holding of the fruit. The experiment is being continued during the present season on a schedule which reduces the temperature to 32° by November 15.

Apple Washer. (C. I. Gunness.) The construction of an apple washer was reported in last year's annual report. Some further work has been done on this washer, and trials indicate that apples are handled with very little bruising, spray residue is removed satisfactorily, and the final rinsing removes the acid quite completely. A detailed report of the test is made by the Department of Entomology.

Pump Testing. (C. I. Gunness.) In former years mention has been made of the testing of low-lift pumps used by cranberry growers. During the past year a pump testing plant has been built at the college for the testing of pumps and for the study and development of efficient types of pumps suitable for cranberry bogs.

Rural Electric Survey. (C. I. Gunness.) During the past year a survey of the use of electricity on farms has been carried on. Records were obtained on 7131 farms or approximately one-half of the farms in the State now having electric service. A classification of these farms indicates that the so-called general farm uses 980 kilowatt-hours per year, the poultry farm 1480 kilowatt-hours, and the dairy farm 1726 kilowatt-hours. The average annual consumption on all farms is 1303 kilowatt-hours.

A detailed study was made of 1563 farms having at least 5 cows, or 100 hens, or a fruit or general business which would make them qualify as real farms. The use of current on these farms has increased from 976 kilowatt-hours in 1929 to 1735 kilowatt-hours in 1933. About 24 per cent of the dairy farms in this group are equipped with milking machines, and 30 per cent with electric milk coolers.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Pasture Experiments. (A. B. Beaumont.) Lime and complete fertilizer were applied to permanent pasture plots in Worcester County in the fall of 1933 and spring of 1934. No yields were taken, but observations showed the usual marked response to nitrogen, potash, and lime. The response to potash was particularly outstanding in the latter part of the season, due to the abundance of white clover.

Since 1930 a test of the more important nitrogen fertilizers has been conducted on a strongly acid, depleted, upland pasture soil in Amherst. Judged by yield of grass, calcium nitrate and sodium nitrate have been distinctly superior to ammonium sulfate, ammonium chloride, calcium cyanamide, and urea when applied in addition to lime, phosphoric acid, and potash.

Legume Variety Tests. (A. B. Beaumont.) Cooperative tests of varieties of miscellaneous legumes were terminated in 1934 by the disastrous effects of the extremely cold winter of 1933-34. Seedings of alfalfa varieties ranging in age from one to five years were 90 to 100 percent killed. The injury appears to have been due primarily to the formation of an extensive ice sheet which persisted for a long enough time to smother the plants. There was little or no relation between killing and variety, but Hardigan showed somewhat more resistance to this condition than did other varieties.

Results of tests of varieties of soybeans were published in 1934 as Bulletin 309, entitled "Soybeans for Massachusetts." Results of tests of other legumes will be published in detail by the Bureau of Plant Industry of the U. S. D. A., which cooperated in the work. Since publication will be delayed somewhat, the following brief summary is given.

Alfalfa. Twenty-one varieties from many domestic and foreign sources were tested. The oldest seeding was 5 years old when terminated. During this period yield of varieties did not appear to be associated definitely with the latitudinal source of seed nor with factors commonly accepted as indicating hardiness, such as variegation of the blossoms. Hardigan was the most consistently high-yielding variety, but the yield of Grimm was about the average of the various lots tested. Both of these varieties have variegated blossoms. With the exception of common alfalfas from California, which were consistently among the lowest producers, all strains of common alfalfa, including those from Dakota, Kansas, Utah, Oklahoma, and New Mexico, were quite satisfactory and gave average or better than average yields. Kansas and Utah common were generally the most productive of this group. Among the foreign varieties, Hungary, Argentine, and Italian were good yielders. Ladak, Turkestan, and Hairy Peruvian were definitely poor in these tests. Poor yields generally were associated with weak stands developed during the period of the experiment.

Red Clover. During the period 1930-1932, 43 lots of red clover strains were grown in three seedings. Results clearly show the supremacy of domestic over foreign varieties, and of eastern domestics over western domestics. The highest average yield for the strains of a given locality was 3.4 tons of cured hay.

Crimson Clover. Tests of crimson clover sown alone and with oats, and at different times from early May to the middle of July in 1932 and 1933, showed that when treated as a summer annual this legume is not well adapted to this (Connecticut Valley) section. The maximum yield when seeded alone was 1.3 tons of cured hay.

Field Peas and Vetches. Several varieties of field peas were grown alone or in combination with oats as a companion crop. In this section peas are subject to the attack of several insect pests and fungous diseases, of which aphids are the worst, and infestations of them occur with considerable regularity. Spells of hot weather usually occurring in May or June also are a deterrent to the best development of peas. Of several varieties of peas tested, Chang gave the highest average yield (1.33 tons of cured hay). The maximum yield in the best year was 1.75 tons when the crop was grown without a companion crop. The use of oats as a companion crop reduced the yield of peas, but increased the total yield, reduced insect and disease injury, and is recommended as a practical method. Vetches, likewise, did poorly. Of the spring-sown varieties, Oregon Pearl did best, and of the fall-sown varieties, Oregon Hairy was slightly superior. As with peas, this crop did best when sown with a companion crop; winter wheat was slightly better than winter rye for fall-sown vetch, and oats were satisfactory for the spring-sown crop. These tests have shown that field peas and vetches are not well adapted to such conditions as prevail in the Connecticut Valley. They should be regarded primarily as emergency forage crops, but not as permanent substitutes for red or alsike clover, alfalfa, or soybeans, which yield considerably more per acre.

Lespedeza. Two strains of Early Korean lespedeza were tested for seed production in 1932 and 1933. These were grown in cultivated rows on a soil of good fertility. Both strains set seed abundantly and matured them by the middle of September. The plants attained a maximum height of about 10 inches. No data on yield of forage were obtained. It has been suggested that this variety of lespedeza might be successfully grown on acid, upland pasture soils. In the spring of 1933 before the frost had come out of the ground, seed of both strains was sown at the rate of 20 pounds per acre on the surface of a permanent pasture which had been used for fertilizer experiments. The sod was quite thin in places. Early in the season and before grazing had begun, a fair stand of lespedeza plants was found on all plots, but at the end of the grazing season less than 1 percent of lespedeza could be found on any plot. Such plants as were found were very small, but had set seed. No differences were apparent in strain of seed, or fertilizer or lime treatments. By the end of the grazing season of 1934 lespedeza had virtually disappeared from the pasture. It seems that this legume cannot be established in this manner on upland pastures of this section.

Sweet Clover. Hulled and unhulled seed of biennial white sweet clover was sown on the surface of plowed and harrowed soil at monthly intervals from December to May. It was found that maximum stands and good yields were obtained from seedings of December, January, and February. Results were progressively poorer from March to May. It appears that winter seeding of sweet clover in this manner may be very practical, and either unhulled or hulled seed may be sown. Some of the seedings were on the surface of deep snow.

Field Experiments with Tobacco. (W. S. Eisenmenger, A. B. Beaumont, and M. E. Snell.)

Cropping Systems. The tobacco experiments reported in 1933 have been continued. No lime was added to the soil during the past year, and the pH has remained at approximately 5.0. The soil, in addition to lending itself to attack of "brown root-rot" of tobacco, also contains *Thielavia basicola* (black root-rot organism) in sufficient quantities to be harmful to the crop.

The following are the yields that have resulted from different treatments under the same conditions of fertilization:

	Pounds per Acre
Check plots without lime	1732
Check plots with lime	1587
Red top cover crop	1832
Clover cover crop	1666
Spring wheat cover crop	1677
Oats cover crop	1690
Barley cover crop	1737
Manure (no cover)	1852
Manure and red top cover crop	1786
After clover hay (old animal husbandry plots)	1991
After clover hay (new animal husbandry plots)	1699
After timothy hay (old animal husbandry plots)	1217
After timothy hay (new animal husbandry plots)	2014
Corn stover applied to tobacco soil plots	1755
Check	1659
Corn stubble removed	1860
Check	1921
Corn soil treated with orthocresol	1772
Check	1553

Form of Nitrogen. In this experiment, one-half the nitrogen applied in fertilizers comes from cottonseed meal and the other half from one of five nitrogenous fertilizer materials. The experiment has now run three years. For the entire period of the experiment the highest mean yield of tobacco has been produced by the standard fertilizer mixture (nitrogen ½ from cottonseed meal, ¼ from calurea, and 1/8 each from nitrate of soda and nitrate of potash), followed closely by calcium cyanamide, nitrate of soda, sulfate of ammonia, and urea, in order. The differences obtained thus far are hardly significant, although rather consistently in the same direction.

Proportion of Organic Nitrogen. In this experiment, which has run three years, fertilizer mixtures containing different proportions of nitrogen from cottonseed meal and inorganic sources are compared with each other and with the standard mixture used in all experiments with tobacco at this station. In 1934 the highest yield (2127 lbs. per acre) was obtained from the standard mixture (containing ½ organic nitrogen), followed very closely by that from the mixture containing 1/8 organic nitrogen and 7/8 inorganic nitrogen. For the period of the experiment, the mixture containing 1/8 organic nitrogen has yielded the most tobacco, but differences among yields from all mixtures have been small. The sorting quality of tobacco for 1932 and 1933 was slightly better from mixtures containing ½ organic nitrogen.

Method of Applying Fertilizer. This experiment was continued in 1934 with the same methods and equipment as were used in 1932 and 1933. The average yields were as follows:

Row Application	Pounds per acre	Broadcast Application (Check)	Pounds per acre
4/8 Standard amount......	1737	Standard amount.........	2032
5/8 Standard amount......	1759	Standard amount.........	2022
6/8 Standard amount......	1798	Standard amount.........	1994

These figures show a greater advantage of the standard (full) amount broadcast than has been shown in the preceding four years of this experiment. The experiment should be continued to determine whether the differences obtained represent anything more than a seasonal variation. Such data as have been obtained on sorting quality of the crop grown under the two methods of fertilizer application show no significant difference.

Toxicity of Aluminum for Tobacco. (W. S. Eisenmenger.) As reported in 1933, tobacco plants were grown in aluminum citrate solution for two-day intervals and on the alternate two days in a complete nutrient solution. The decided toxicity begins at about 17 ppm. of aluminum.

Other plants were grown in solutions containing aluminum citrate and calcium nitrate in relative proportion of 0.006 M of each salt represented as follows in terms of percentage molecular proportions:

Aluminum Citrate	Calcium Nitrate
100	0
95	5
85	15
75	25
50	50
15	85
5	95
0	100

The results would indicate that the calcium ion was a decided factor in overcoming the toxic principle of the aluminum.

Distribution of Nitrogen in Soils Mixed with Different Plant Tissues and Allowed to React for Six Months. (W. S. Eisenmenger and W. J. Moore.) As a sequel to the determination of forms of nitrogen in infusions, an attempt is being made to perform similar determinations on plant tissue under more aerobic conditions. One part of chopped plant tissue was mixed with two parts of soil in crocks and allowed to stand in the greenhouse. Water was added to keep the soil approximately moist enough to grow plants. At the end of a six-month period the materials are being analyzed for nitrogen, total nitrate, ammonia, amide, alpha amino acid, protein, and humin. The plant tissues used were red clover, alfalfa, red top, timothy, corn, and tobacco.

The Relationship of Mineral Nutrients to the Nitrogen Content of Tobacco Plants. (W. S. Eisenmenger and H. R. Knudsen.) Tobacco plants were grown in different ratios of elements, according to the triangular system used earlier by Schreiner and others, to determine the approximate ratio at which plants thrive best. Also the relationship of nitrogen, ammonia, and nitrate content of each plant to the relative abundance of either phosphorus, potash, and nitrogen in the medium is being determined.

Magnesium Requirement of Crops. (A. B. Beaumont and M. E. Snell.) Barley, Sudan grass, millet, rutabagas, turnips, mangels, spinach, peppers, sweet corn, and field corn were grown in this experiment in 1934. This experiment in its present form has now run 6 years. Including tobacco, grown in the previous experiment, and alfalfa and red clover, grown in pots in soil taken from the experimental field, 20 varieties of field and garden crops have been studied. These crops have differed to a marked degree in their reaction to magnesium deficiency, in yield as well as in physiological symptoms. Buckwheat and spinach were most affected; turnip, mangels, corn, and tobacco considerably; the small grains, grasses, clovers, alfalfa, and potatoes were only slightly affected; and others hardly or not at all. Plants sensitive to magnesium deficiency developed characteristic physiological symptoms which have diagnostic value. Chlorosis of the older leaves developed in the intervascular tissue. In leaves of plants with parallel veins this produced a striped appearance; while in leaves having netted venation, a mottled chlorotic pattern was produced. Results of this experiment for 6 years have been summarized for publication.

Onion Set Production. (M. E. Snell.) During the past summer two new phases of growing onion sets of desirable size for planting have been studied: first, the possibility of controlling the size of set by time of pulling; and second, the effect of later planting on development of desirable sets. It was found that within broad limits it was possible to control the size of sets by time of pulling. By this method one can seed quite heavily (50 or more pounds per acre) and fertilize heavily enough to get good strong growth (1000 pounds per acre on fair onion land), and by spreading the seed well over a broad row get very large yields of sets, with a high percentage of them of any desired size. The past season's results would indicate that good sets may ordinarily be produced by planting as late as May 20. This would sometimes be an advantage, as planting early while the ground is still cold and wet often gives very poor germination.

The sets grown during 1933 were stored for about six months to check the previous year's findings on keeping quality. The storage loss was somewhat less than for the 1932 sets. In respect to size of set, keeping quality compared favorably with the 1932 results. Different fertilizer treatments did not seem to make any material difference in keeping quality of sets.

Sets from each fertilizer treatment (with commercially grown sets as checks) were again planted to study influences on yield of first-grade bulbs and production of seed stalks and multiple bulbs. Marked difference between the two sizes planted was found in development of seed stalks and multiple bulbs, but the net yield of first-grade bulbs was nearly the same in all cases. None of the fertilizer treatments showed marked differences, however, in any respect.

Onion Breeding. (M. E. Snell.) The past summer was very favorable for breeding work. Seed production was particularly good with most of the selfed bulbs, but not so good with the crosses which were attempted. Many good groups of bulbs were grown from seed sown in the field, as well as a number of very good lots of sets for planting. For the first time seed from some of the inbred strains and crosses was planted in the greenhouse and later transplanted to the field, with very good results. This method permits a much greater number of bulbs suitable for parent stock to be grown from limited amounts of seed than where planted directly in the field. It was interesting to observe the marked uniformity of top growth of these transplants from seed which had been inbred for several generations. There was also an opportunity to observe differences in time of normal maturity, which is very seldom possible with onions which are grown from seed sown in the field. The onions grown from sets were also very good in some cases, but frequently a strong tendency to develop seed stalks and multiple bulbs was observed. This is very good evidence that heredity plays an important part in this respect. Several of the strains were sufficiently lacking in one or both tendencies to indicate that much can be done by way of selection to reduce this undesirable though natural tendency of set onions.

Study of Base-Exchange Power and Base Content of Typical Connecticut Valley Soils as Influenced by Heavy Liming and Fertilization. (J. L. Haddock and H. H. Coyle, Jr.) It has been recognized for many years that soils differ in many ways and that all cannot profitably be handled in the same way. In spite of this rather universal understanding we diagnose the trouble and apply the remedy for all soils in a blanket manner regardless of the soil under consideration.

During the spring and summer of 1934, an investigation of three of the most prominent and intensively cultivated soil series of the Connecticut Valley was begun. The object of this investigation was to determine: (1) the possibility of characterizing each soil series as to its possible strength or weakness in available bases; (2) the effect of cropping and fertilization upon the base-exchange Ca, Mg, K, and Na, in the various horizons; (3) the degree of base-saturation in the various horizons of cropped and natural soils of the same series.

The study thus far has indicated that in spite of heavy fertilizer and lime treatment the exchange-bases remain remarkably constant, even on light, sandy soils. The greatest influence on the availability of these bases seems to be the total exchange power of the soil. This is, of course, influenced by texture and soil humus.

The Absorption by Food Plants of Chemical Elements of Importance in Human Nutrition. (A. B. Beaumont in cooperation with E. B. Holland.) A new project under this title was started in the spring of 1934. Spinach and white egg turnips were grown in succession in a fine sandy loam placed in cement tanks. In an attempt to increase the absorption by the plants of certain elements, increasing quantities of chemically pure compounds were applied to the soil in addition to a uniform application of a fertilizer containing N, P and K. Allowances were made in the fertilizer for K and P in the additional material. Aside from the uniform fertilizer treatment, the applications were as follows:

	Kg per hectare
Calcium sulfate $(CaSO_4.2H_2O)$	2000 4000 6000
Calcium phosphate, primary $(Ca(H_2PO_4)_2.H_2O)$	1464.5 1929.0 4393.5
Potassium iodide (KI)	8 16 24

Yields of the two crops from the several treatments were rather uniform. The medium application of potassium iodide increased the yield of turnips, but not of spinach, more than any other treatment, but the difference was not great enough to be considered statistically significant. Chemical analysis of these crops is being made.

In another experiment under the general project of absorption of chemicals, a preliminary pot experiment was conducted with the same type of soil as that used in the tanks mentioned above, for the purpose of determining the limits of tolerance of plants for iron and copper compounds. Ferric oxide, ferric sulfate, ferrous sulfate, and copper sulfate were applied to unlimed and limed soils having reactions of pH 4.4. and 5.4 respectively, at rates of 10, 20, 40, 80, 160, 320, 640, 1280, 2560, and 5120 pounds per acre. A marked difference was noted in the concentration of materials causing injury in soils of different reactions, toxic concentrations being lower in the more acid soil; but ferric oxide was not toxic in any concentration used. Spinach and turnips were grown in succession in the same soil. Concentrations at which toxicity definitely appeared were as follows:

Crop	Soil Acidity (pH)	Pounds per Acre Causing Injury		
		Ferrous sulfate	Ferric sulfate	Copper sulfate
Spinach......	4.4	1,280	640	320
	5.4	5,120	2,560	1,280
Turnips......	4.4	640	320	160
	5.4	...*	...*	1,280

*Not toxic in concentrations used.

Potato Variety Tests. (E. F. Gaskill, R. W. Donaldson, and W. S. Eisenmenger.) An increased interest in potato production in Massachusetts led to a yield test of several of the varieties considered adaptable to New England conditions. The results from plots one-eleventh acre in area showed the following yields calculated on an acre basis: Green Mountain, 635 bushels; Chippewa, 635; Russet Rural, 593; Katahdin, 506; and Golden, 456.

A compilation of results from quality tests indicates the following:

Green Mountain: Good flavor, dry and mealy when either boiled or baked, attractive white color. Many of these potatoes were too large for market, a few were hollow hearted, and they had a decided tendency to throw prongs.

Chippewa: Good flavor, dry and mealy, attractive white color, shallow eyes, smooth, and very even size.

Katahdin: Good flavor, dry and mealy, attractive white color, very smooth, seem to take a little more time to cook.

Russet Rural: Good flavor, dry and mealy, seem to require more time to cook than any of the preceding varieties. Too mealy when boiled, but very satisfactory when baked. Skin rough, dark, and not attractive. Size very even, very few large or pig potatoes.

Golden: Poor flavor, rather flat, the least mealy of the five varieties. Objectionable yellow color. This variety tends to sprout early, several potatoes having started to sprout as early as October 15.

Annuals as Emergency Hay or Green Manure Crops. (E. F. Gaskill, R. W. Donaldson, and W. S. Eisenmenger.) Plantings of summer annuals were made June 1 to determine their relative yields for emergency hay or green manure crops. Soybeans were sown in 30-inch rows at the rate of 1 bushel per acre, and broadcast and drilled at the rate of 2 bushels per acre. Soybeans (2 bushels per acre) were mixed with either Japanese millet, Hungarian millet, or Sudan grass (10 pounds per acre) and sown broadcast. Soybeans were sown in 30-inch rows and the millets and Sudan grass seeded after the soybeans were 4 inches high. Results for this season indicated that the mixtures sown broadcast — soybeans and Japanese millet, soybeans and Sudan grass, soybeans and Hungarian millet — ranked first, in order named, as regards yield, weed control, and ease of harvest.

Fine Turf Grasses. (L. S. Dickinson.) On November 30, 1934 all field plots of fine turf grasses were discontinued, with the exception of a series of 32 plots repeated four times, and used to continue investigations concerning the need of pre-seeding fertilizers for lawns and fine turf areas.

The pre-seeding fertilizer studies were started in 1930, the grass beng grown in boxes in which heat, fertilizer, soil, and water were controlled. In 1931-1932 the studies were repeated but with only soil and fertilizer controlled; the boxes were placed out of doors and the grass was subjected to the daily weather conditions. In 1933-1934 the studies have been conducted on typical fine-turf soil, and with the grass growing under natural conditions. To date, the results obtained correlate very closely and it is becoming more obvious that on normal soils, a single phophorus carrier is all the pre-seeding fertilizer that is necessary or desirable for the fine turf grasses, Colonial bent and Kentucky blue grass.

Some progress was made in an attempt to classify the soils on the best and poorest putting greens, for the purpose of establishing definite soil standards; but lack of funds made it necessary to discontinue the work before definite results could be obtained.

Further tests were made with a non-mercuric fungicide for the control of certain fungous diseases of turf grasses. The tests showed the fungicide to be effective on laboratory cultures and against weak fungous attacks in the field.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in Cooperation with the Massachusetts Agricultural Experiment Station

C. V. Kightlinger, U. S. D. A., in Charge

Black Root-Rot. (C. V. Kightlinger.) In continued investigation, numerous strains of Havana Seed tobacco were tested comparatively in the field in 1933 (the fourth year of the investigation), in the attempt to find strains which will be satisfactory under Connecticut Valley conditions for resistance to black root-rot, type of plant, type and quality of leaf, and gross producing capacity.

One strain was Havana Seed of the sort that is grown commonly in the Connecticut Valley. When grown under favorable conditions, it is acceptable for type of plant, type and quality of leaf, and gross producing capacity, but it is susceptible to black root-rot. This strain was used as a standard for rating new strains for type and quality. Another strain was Havana Seed 142A3 which is satisfactorily resistant to black root-rot, and is ordinarily satisfactory for gross producing capacity under conditions favorable to the development of the disease. This strain was used as a standard for rating new strains for resistance to black root-rot and gross producing capacity under such conditions. Seventeen strains were tested in 1933, four of which had been grown for the first time in 1930, five in

1931, five in 1932, and three were first grown in 1933. In one case all of the strains were grown on land which was relatively free of black root-rot promoting conditions. In another case all of the strains were grown on land which was favorable to severe development of the disease. Twelve of these new strains were selected for further testing in 1934.

The production of these twelve new strains and the controls in 1933 was as follows:

Strains of Havana Seed Tobacco		Grown on land relatively free of black root-rot promoting conditions			Grown on land favorable to severe development of black root-rot		
		Yields per acre Pounds	Grade index	Crop index	Yield per acre Pounds	Grade index	Crop index
Common strain		2077	.394	818	1445	.352	509
142A3		2159	.415	896	2012	.383	771
New strains	No. 13	2203	.412	908	1974	.437	863
	No. 18	2148	.414	889	1890	.403	762
	No. 22	2112	.408	862	1854	.431	799
	No. 23	2006	.418	839	1944	.428	832
	No. 25	2169	.414	898	2210	.444	981
	No. 27	2128	.417	887	2066	.431	890
	No. 29	2379	.406	966	2236	.429	959
	No. 30	1895	.416	788	1743	.410	715
	No. 31	2345	.411	964	2168	.415	900
	No. 32	2135	.392	838	1947	.411	800
	No. 33	1879	.438	823	1658	.408	676
	No. 34	1933	.418	808	1881	.389	732

The grade index is a number expressing the grading quality produced by a strain of tobacco under the conditions of the experiment. It is based upon the percentage yield of each grade of tobacco and the relative values of the different grades, which are as follows:

Light wrappers	1.00	Long darks (19″ and longer)	.30
Medium wrappers	.60	Dark stemming (17″ and shorter)	.20
Long seconds (19″ and longer)	.60	Fillers	.10
Short seconds (17″ and shorter)	.30	Brokes	.10

The grade index is arrived at by multiplying the percentage yield of each grade by its respective rating given above, and adding the products. The crop index is a number expressing relative crop value. It is derived by multiplying the total production of tobacco in pounds per acre by the grade index value. Grade index and crop index, and the adopted relative values of the different grades of tobacco given above, do not necessarily represent current commercial values and prices.

All of these new strains of Havana Seed tobacco have proved to be satisfactorily resistant to black root-rot. With respect to type, some of these strains closely resemble certain good strains of common Havana Seed tobacco; and with respect to yield and quality, they almost always surpass the common strains.

Strains 13, 22, and 29 have proved to be sufficiently promising in small plot tests to justify trial on a considerably larger scale in numerous localities in the Connecticut Valley, in order to determine their worth in practical culture. Strain 13 was grown on larger acreage in one locality in 1933 and in this instance proved to be highly satisfactory. Strains 13 and 22 were grown in larger acreages in several localities in 1934. Strain 13 proved to be satisfactory in all cases, and strain 22 in all cases except one. Arrangements have been made for testing strains 13, 22, and 29 on a larger scale in 1935.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

As noted elsewhere (see report of Chemistry Department), the work in animal nutrition formerly carried on by that department was transferred during the year to the Department of Animal Husbandry. One old project has been brought to completion and another is being continued in cooperation with Chemistry (see report of that department), and two new projects have been organized.

The Proper Supplementary Ration for Milking Cows on Pasture. (J. G. Archibald, V. A. Rice, R. C. Foley, and C. H. Parsons.) This project is a further development of work done in 1931 and 1932 on the possibilities of greatly reducing the grain fed to cows on pasture. The abnormally dry season and consequent short pasturage interfered somewhat with the progress of the work but some results were secured that appear significant.

One group of cows receiving only 43 percent as much grain as did another group gave 93 percent as much milk, maintained their weight, and did not show a markedly higher shrinkage in milk flow (37.3 percent contrasted with 34.9 percent). The ratio of grain fed to milk produced in this group was 1: 10.7 for the entire season, while in the other group it was 1: 4.3. From May 21 to July 20 it averaged 1:12.8 for the low grain group and at one time in June was as wide as 1:14.8, some of the cows receiving no grain at all. The tentative conclusion has been drawn that "the necessity for even moderate grain feeding when pastures are good is not apparent." The work will be repeated next season.

The Relative Efficiency for Milk Production of Proteins from Animal and Vegetable Sources. (J. G. Archibald, V. A. Rice, and C. H. Parsons.) This project has only recently been started. This season the relative value for milk production of dry rendered tankage versus a mixture of soybean meal and cottonseed meal is being investigated. Twenty-four cows are included in the trial, being divided into two groups of twelve each, which are fed identically except that about half of the protein for one group is obtained from tankage, and a similar amount for the other group is from soybean and cottonseed meals. The cows are being fed by the double reversal method, feeding periods being thirty days in length with a preliminary period of ten days. The experiment will continue to the close of the barn feeding season in April, 1935.

The Comparative Efficiency of Dairy Cattle in Converting Feed into Milk. (V. A. Rice and W. T. Smith.) This study was divided into three phases. First, a preliminary study was conducted with six Holstein Advanced Registry Class A test cows in the Massachusetts State College dairy herd. These animals varied from two to ten years in age, and from nearly fresh to eleven months along in lactation. An accurate record was kept of all feed consumed and all milk produced for one week.

For purposes of computation and comparison, the milk of each cow was reduced to a 4 percent fat corrected basis according to Gaines and Davidson's formula (4/10 M.+15 F. where M.=Milk and F.=Fat). The amount of T. D. N. ingested was ascertained and the amount of T.D.N. yielded in the milk. The latter figure divided by the former gave the average efficiency of converting feed into milk, which for this group was 32.22 percent.

Second, a number of records as compared in the Guernsey Advanced Register, volumes 18 to 21, were studied by similar methods, and an average efficiency of 31.20 percent was found.

Third, the records of the mixed Holstein and Jersey herd of the Massachusetts Agricultural Experiment Station for the years 1920 to 1933 inclusive were studied by similar methods. They included a total of 42 cows with 136 lactations. The results gave a range of efficiency from a low of 18.12 percent to a high of 39.60 with an average of 29.35. That is to say, on the average, these cows returned 29.35 pounds of total digestible nutrients in the form of milk for every 100 pounds of total digestible nutrients fed.

The following four points seem well established.

1. There was a gradual rise in efficiency of feed conversion with age from two years to about nine years.
2. The cows that showed a low efficiency at two years were low all through their lives, and those high at two years were high throughout their lives.
3. Percentage efficiency of feed conversion is apparently an inherited quality.
4. As would be expected, there was a positive correlation between amount of production and efficiency; that is, the higher producing cows were the more efficient converters.

Inheritance of High Milk Production in the May Rose Family of Guernsey Cows. (V. A. Rice.) A study was made of all the direct male offspring of the Guernsey bull, May Rose King, through his 15 sons, their sons, grandsons, etc. In this way it is possible to trace the lines of high production back to their source, and to ascertain which lines of breeding at the present time are the more homozygous for high milk production.

Further studies along this line will reveal the methods of breeding which have given rise to these more homozygous strains.

A Study of Bull Indexes and the Formulation of the Intermediate Bull Index. (V. A. Rice.) The Mount Hope Index, based on the theory of partial dominance of high milk production and low fat percentage, the Gifford Index, using merely the daughters' records, and the Intermediate Index, suggested by the author, with the offspring placed halfway between the cows' level of production and the assumed index, both for amount of milk and percentage of fat, were studied for their accuracy and reliability from the standpoint of prognosticating the production of future daughters of a bull after his index has been achieved through the production records of his first ten daughters. The results showed that all three methods were remarkably accurate, but that the Intermediate method was the best.

Further studies were made to determine the value of the Intermediate Index in foretelling the production of the daughters of young untried bulls. The method was to obtain indexes on the sire and two grandsires of the young bull, which were used as the transmitting level of these male animals. The transmitting level for the dam and two granddams was the average of (1) the cow's own record, (2) the index of her sire, and (3) the cow's own index calculated from her daughters' records and the indexes of the sires of said daughters. It was found that a figure comprised of 6/10 of the average of the parental indexes and 4/10 of the average of the grandparental indexes was, on the average, within 6 percent of accuracy.

The Comparative Efficiency of Lambs in Utilizing Feed. (Ralph W. Phillips.) Ten lambs were fed individually for four months and accurate records and analysis of all feeds consumed were obtained, the object being to determine what individual differences exist in the efficiency with which lambs transform feed into meat. The lambs were approximately seven months old when the feeding trial began, and all received the same ration.

Striking variations in efficiency were noted, the most efficient lamb requiring 6.09 pounds T. D. N. per pound of gain and the least efficient 11.63 pounds T. D. N. per pound of gain, an increase of 90.9 percent in the cost of a pound of gain.

The above figures indicate an obvious advantage in developing a more efficient strain of sheep. Plans for the continuation of this work include the testing of the efficiency of offspring of the lambs mentioned above, and of future offspring of the dams of the lambs already used, to determine whether or not the ability to utilize feed efficienctly is inherited.

The Development of the Tunica Dartos Muscle in Rams. (Ralph W. Phillips.) Recent experimental work has demonstrated conclusively that the scrotum has a thermo-regulatory function maintaining the testes at a temperature below that of the body cavity, and that the tunica dartos muscle provides the mechanism for this temperature regulation, functioning very much as a thermostat to maintain a fairly constant temperature.

The reaction of isolated strips of the tunica dartos to temperature changes was observed in ram lambs at 3, 6, 9, 12, 15, 18, 21, 24, and 27 weeks of age. The first marked reaction to a temperature change was observed at 12 weeks of age. In lambs castrated before 12 weeks of age the tunica dartos had not developed a sensitivity to temperature changes; and in lambs castrated after this sensitivity developed, there was a tendency for the sensitivity to be lost after a period of time.

The above results indicate that the development of the temperature sensitivity is dependent upon some substance, probably the testes hormone. The stage of development of testes removed at the time of studying the dartos strips is being studied, and further work is being planned to test the above hypothesis.

Progeny Performance in Sheep. (Clarence H. Parsons.) A cooperative project with the U. S. D. A. was started in 1932 using the Southdown and Shropshire flocks of sheep in order to determine the inherent capacity of specific families or strains of sheep for the utilization of feed and the production of meat and wool, and to improve them by a study of the manner in which they transmit these characters.

A specialist from the Bureau of Animal Industry of the U. S. D. A. visits the college each fall to counsel with a committee from the college in grading the type and body characteristics of all lambs born that year. He also visits the college each spring at shearing time to assist in grading and sampling the wool from all the sheep. The carcasses of all sheep slaughtered at the college are graded. The sheep are weighed regularly and accurate feed records kept.

This work provides a definite and complete record of each sheep which may be used for comparing daughters with their dams, etc., and which is on file after the individual is no longer available for inspection. The contact with a specialist of the Bureau of Animal Industry helps to keep the records uniform and comparable with similar records at other institutions. The records of this work will be of increasing value as time goes on and more records are available. Already much valuable information has been secured regarding the offspring of a few rams, and the present Southdown ram was secured on the basis of similar records kept on his lambs at the Morgan Horse Farm, Middlebury, Vermont.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

The Azotobacter Soil Plaque Test for Determining Soil Nutrient Deficiencies. (James E. Fuller.) This was a continuation of an investigation previously reported (Mass. Agr. Expt. Sta. Bul. 305, p. 15, 1933). The technique of Sackett (Colo. Agr. Expt. Sta. Bul. 375, 1931) was employed in setting up the soil plaque tests. Because the presence of Azotobacter in the soils tested could not be depended on, all plaques were inoculated with Azotobacter. In addition all plaques were treated with calcium carbonate, and mannite was used as a source of energy. Chemical tests for available phosphorus were made according to the technique of Truog (Jour. Amer. Soc. Agron. 22:874, 1930). The soils examined were from ten of the college farm and experiment station plots and from three private garden plots. The soil plaque tests indicated that all of the soils were deficient in available phosphorus, in spite of the fact that all of the plots represented produced satisfactory crops. The Truog tests revealed a rather wide variation, but no actual deficiency in the available phosphorus of the soils. The study indicated that the Azotobacter soil plaque test is not a dependable indicator of the available phosphorus content of the rather acid sandy loam soil which is common in this region. Our results agreed with those published by Walker and associates (Jour. Amer. Soc. Agron. 22:642, 1930). Details and data will be furnished on request.

Calcium Metabolism of Nitrogen-Fixing Bacteria. (James E. Fuller.) This study was undertaken on the premise that calcium might exert some stimulating influence, aside from the neutralization of acids, on the metabolism of Azotobacter. Twelve strains of Azotobacter, freshly isolated from soil at the beginning of the experiment, were cultivated on a medium free from calcium (the medium was composed of K_2HPO_4, mannite, and distilled water). Nitrogen-fixation on the medium was determined and compared with nitrogen-fixation on the same medium to which varying quantities of calcium carbonate were added. As much nitrogen was fixed on the calcium-free medium as in the presence of any of the quantities of calcium carbonate, and as the concentration of calcium carbonate was increased the amount of nitrogen fixed was apparently decreased. Cultures grown on Ashby's medium gave the smallest amount of nitrogen fixed in the study. The twelve Azotobacter strains, after being cultivated for two years on the calcium-free medium, appeared to have unimpaired nitrogen-fixing power. Results were the opposite of those anticipated, and lime appeared to be unimportant in the nitrogen-fixing metabolism of the organism. The medium employed contained no demonstrable calcium except that purposely added.

The Influence of Bile and Bile Salts on Bacterium Aerogenes. (James E. Fuller.) The purpose of this study is to investigate the possibility that *Bacterium aerogenes*, generally regarded as a non-fecal organism, may acquire characteristics of *Bacterium coli* of fecal origin. Twenty-five strains of *Bacterium aerogenes* isolated from water were chosen. These strains were proved, by repeated tests, to be negative for the methyl red test and positive for the Voges-Proskauer, sodium citrate, and uric acid tests. These strains have been cultivated for three months in a fluid medium composed of one percent each of Difco peptone, Difco lactose, and K_2HPO_4, in distilled water. The strains were set up in three series of cultures: to one was added one percent of sodium taurocholate; to another one percent of sodium glycocholate; and to the third one percent of ox bile. Incubating temperature was 37°C. Cultures were transferred once each week, and once each month they were tested for their methyl red, Voges-Proskauer, sodium citrate, and uric acid reactions. To date the cultures have shown a tendency to give variable reactions to the Voges-Proskauer test. The reactions to the other tests have not changed. This study is a part of the project on the biological studies of bacteria of the Coli-Aerogenes group.

The Bacteriostatic Action of Dyes with Gram Positive Cocci. (James E. Fuller and Morrison Rogosa.) It is common practice to employ one or more dyes in a presumptive medium for water analysis, to inhibit the growth of gram positive bacteria which might interfere with the tests for the Coli-Aerogenes group. This study was undertaken to determine the concentrations of gentian violet, crystal violet, basic fuchsin, and acid fuchsin which would prevent the growth of gram positive cocci (staphylococci, hemolytic and non-hemolytic streptococci, sarcinae, and micrococci). Basic fuchsin exerted the most pronounced bacteriostatic effect, crystal violet and gentian violet following in the order named. Acid fuchsin had little bacteriostatic effect under the conditions of the experiment. Streptococci were more resistant to the dyes than were the other organisms studied. Acid production by the various organisms was studied, and it appeared that organisms which produced more acid were more resistant to the dyes employed. Excellent and extensive studies of bacteriostatic action of dyes have been reported by Churchman and by Stearn and Stearn. The present study was carried out in more specific detail than their work. This was related to the project on the biological studies of the Coli-Aerogenes group.

The Indol Tolerance of the Coli-Aerogenes Group of Bacteria. (Ralph L. France.) The results of this investigation indicated: (1) that the indol tolerance of the various strains under investigation cannot be used as a basis for differentiating the fecal forms from the non-fecal forms; (2) that a dilution of 1:2,000 of indol inhibited the growth of all the strains studied; and (3) that there was a greater variation in the indol tolerance of the non-fecal aerogenes strains than in the fecal coli strains.

A Study of the Voges-Proskauer Test. (Ralph L. France.) The results of this investigation indicated: (1) that the Leifson's and O'Meara's reagents for indicating the presence of acetyl-methyl-carbinol in liquid media were equally satisfactory, and that both were more satisfactory than the Standard Methods technique or Werkmann's modification of the technique; (2) that the majority of strains of *Bacterium aerogenes* studied produced acetyl-methyl-carbinol in 24 hours' incubation at 37°C.; (3) that a single incubation period of four days resulted in errors, due to the fact that some strains produce acetyl-methyl-carbinol in one, two and three days, but give negative tests thereafter; and (4) that the more accurate method of testing for acetyl-methyl-carbinol production by members of the Coli-Aerogenes group is to set up sufficient tubes to make the test on each of five successive days.

A Comparative Study of Brilliant Green Bile Broth and Dominick-Lauter Broth with the Standard Lactose Broth in Testing Raw Waters. (Ralph L. France.) The results of this investigation indicated: (1) that the Dominick-Lauter broth did not compare favorably with the brilliant green bile broth or the standard lactose broth when used as a presumptive medium; (2) that the brilliant green bile broth was a more satisfactory presumptive medium than the standard lactose broth; and (3) that the so-called "parallel-tubing" method of confirming the lactose broth tubes by inoculation from them into brilliant green bile broth tubes was no more satisfactory than the use of the brilliant green bile broth in place of lactose broth as a presumptive medium.

A Comparison of Several Media for Determining the Bacterial Content of Milk by the Plate Count Method. (Ralph L. France and Bernard E. Supowitz.) The results of this investigation indicated: (1) that the Devereux "yeast extract" agar was not a satisfactory medium for plating raw and pasteurized milk; (2) that an exhaustive study of the nutritive requirements of the common milk organisms is needed; and (3) that an incubation temperature of 32°C. is more satisfactory than the present standard temperature of 37°.

Laboratory Service. (Ralph L. France.) Following is a list of the number and types of examinations made in the laboratory during the past year:

Milk (bacteria counts)	997
Water	80
Miscellaneous:	
*Butter Fat (Milk)	48
*Total Solids (Milk)	1
Sediment (Milk)	7
Added Water (Milk)	1
Throat Swabs	10
Smears	2
Total	1,146

*Analyses made by the Feed Control Laboratory.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Downy Mildews of Cucumber and Lettuce. (W. L. Doran.) Greenhouse cucumbers were sprayed with resin 1:135[1] or Bordeaux mixture 3:3:50, four times at intervals of one week, and inoculated with *Peronoplasmopara cubensis* after the first and third applications. Resin was of some benefit, but was inferior to the Bordeaux mixture in preventing infection. Resin injured the foliage slightly, but more than did Bordeaux mixture.

Cucumbers were grown in soil to which the following salts of copper in these amounts per square foot had been applied: cupric aceto–arsenite (1 to 4 grams), cupric carbonate (2 to 4 grams), cuprous cyanide (2 to 4 grams), copper–lime dust 80-20 (10 to 30 grams), copper sulfate (3 to 5 grams), or copper sulfocarbolate (3 to 6 grams). No protection against infection of the cotyledons of the seedlings by *P. cubensis* resulted.

The dates of the first appearance of downy mildew of cucumber in the fields here (as on September 4 in 1934) have been noted and recorded for the past ten years. Years in which the disease has appeared early (August 4 to 15) have averaged 72 percent more inches of rain and 57 percent more rainy days in July than have years in which the disease appeared late (August 18 to September 4). The weather of August seems to have less effect than does the weather of July.

Infection of lettuce by *Bremia lactucae* was prevented, well and equally well, by Bordeaux mixture 4:4:50, 2:2:50, and 1:1:50, applied 6 times at intervals of one week. Resin 1:125 similarly applied was slightly less effective, and there was very poor control with a 0.35 percent solution of soap. The only one of these materials by which the growth of plants was significantly retarded was Bordeaux mixture 4:4:50.

---

[1] For method of preparation, see Mass. Agr. Expt. Sta. Bul. 293, p. 16, 1933.

Forty strains of lettuce[2] were grown in the greenhouse and inoculated with *B. lactucae* when they were one, two, and three weeks old. Only the following strains seemed markedly resistant to infection: Blonde Pionnel (Clause), Merveille d'Hiver (Clause), Batavia Beau Jolaise (Clause), Batavia White Paris (Bulleri), and May Wonder (Benary).

Eggplant Wilt. (E. F. Guba, Waltham.) Study has substantiated recent published reports that seed carriage of the causal fungus (*Verticillium albo-atrum* R. & B.) may occur. Infected seed was obtainable only from fruit showing the characteristic brownish discoloration of the fibrovascular bundles in the blossom or distal half. A water-bath temperature of 117.5°F. for 30 minutes was lethal to the fungus, while 115° for the same period was not lethal. Preliminary tests indicate that the former hot-water treatment is not injurious to eggplant seed.

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.) The Bewley tomato hybrids which were crossed with Norduke (Mass. Agr. Expt. Sta. Bul. 305, p. 18) show only partial resistance to the leaf-mold fungus *Cladosporium fulvum* Cke. This partial resistance is considered of some value under conditions permitting only light infection and slow development of the disease. Under conditions extremely favorable for infection, this type of resistance is insufficient to make these hybrids suitable for further consideration. It is evident that limited or partial resistance to the disease is all that may be expected from hybridizing varieties within the species *Lycopersicon esculentum* Mill. The hybrids resulting from crossing *L. pimpinellifolium* Mill., a species of tomato immune to the fungus, with three varieties of *L. esculentum* showed in the F_1, a homozygous condition for all characters and immunity; and in the F_2, a heterozygous condition for all characters. Immunity appeared to exist in the ratio of 3:1. Selections from immune individuals are now being grown (F_3 generation) to establish resistant lines and to back cross with the parent varieties of *L. esculentum*, i. e., Belmont, Break O'Day, and Success, for desirable fruit size.

Vegetable Seed Treatments. (E. F. Guba, Waltham.) In a series of trials to determine the value of dry chemical seed treatments on stand of seedlings, the best results were obtained with Cuprocide, Cure-Damp, copper carbonate 18 per cent and 50 percent, zinc oxide, and basic copper acetate. Semesan was generally less efficient. Red oxide compound, Corona P D 7, and basic copper sulfate 52 percent, showed even poorer results. Sanoseed was distinctly unfavorable.

In these tests the dry powders were added to the seed in excess and the surplus removed by screening before sowing.

Causes and Control of Decay of Winter Squash in Storage. (E. F. Guba, Waltham.) Further study has sought to find an efficient, practical method of disinfecting squash prior to storage. Formaldehyde gas generated from 40 percent formaldehyde solution, chlorine from bleaching powder, and sulfur dioxide from burning sulfur were considered. Burning of brimstone at the rate of 5 pounds to 10,000 cubic feet of storage, while possessing excellent disinfecting properties, was injurious to squash. Further work with sulfur dioxide is in progress. Chlorine generated from bleaching powder with hydrochloric acid in increasing ratios up to 2 pounds of powder to 1 pound of acid to 1500 cubic feet was ineffective. Formaldehyde gas generated from 9 ounces of 40 percent formaldehyde solution with 6 ounces of potassium permanganate in 1500 cubic feet for 12- to 24-hour periods in any number of treatments was efficient for all practical purposes.

---

[2] Furnished by Dr. O. H. Pearson of Eastern States Farmers' Exchange.

The optimum temperature for growth of the causal organisms in general is approximately 78°F., with a few exceptions having a higher or lower optimum within the range of 75° to 85°. The maximum temperature for growth is in the range of 92° to 97°, and the minimum generally at approximately 40°, the exceptions at 33° to 35°.

Infection at the blossom end and particularly at the stem end of the squash is of major importance in loss from decay. Injuries in the rind at harvest become overgrown with a firm, thick callus. Inoculations with decay-producing fungi at injuries in the rind during the harvesting season rarely were followed by decay.

The curcurbit wilt bacterium (*Bacillus tracheiphilus* E. F. S.) outranked all other causes of decay combined.

Tests were conducted to determine the relation of seed inoculation with decay organisms and seed disinfection with chemicals to yield and keeping quality of squash, but results do not warrant a report at this time. The trend of the work suggests the importance of insecticidal and fungicidal treatments in the field and cold storage of the harvested crop, study of which is planned in the future.

Strawberry Gold Leaf or Yellows. (E. F. Guba, Waltham.) One and one-half acres of land were planted to yellows-free and otherwise disease-free Howard 17 for plant production. A supply of more than 100,000 plants for distribution to Massachusetts growers will be available in 1935, all of which appears to be engaged.

Carnation Blight. (E. F. Guba, Waltham.) The following are some of the newer varieties of carnations studied for their reaction to the blight fungus (*Alternaria dianthi* S. & H.):

Slightly Susceptible	Resistant
Scarlet Monarch	Orchid Beauty
Light Pink Abundance	Bonanza
Donna Lee	Mrs. M. Beuerlein
	Ocean Spray
	Joy
	Chief Kokomo
	Mary E. Sim

Oxymethylene dusts (6 percent), mixed with sand in the bench in the proportion of 1.5 ounces per square foot, were injurious to the cuttings even after a delay of 72 hours in planting. Potassium permanganate solution 1-1000, applied as a drench to bench sand inoculated with Alternaria and Fusarium sp., was not a satisfactory treatment for controlling infection of the cuttings although the results are not to be considered final. Old solutions of potassium permanganate appeared to be as satisfactory as new solutions for disinfecting carnation cuttings and on root action, although the results are considered indicative rather than final.

Diseases of Herbaceous Ornamental Plants Caused by Soil-Infesting Fungi. (W. L. Doran.) Work has been continued on the effects of certain soil treatments on damping-off and on germination and growth of plants.[3] Liquid treatments were applied to soil (3 inches deep in flats) at the rate of 2 quarts per square foot. The number of grams applied per square foot is indicated below. Reference is here made to post-germination damping-off only. Effects on growth as here mentioned are confined to young plants. Conclusions are tentative, not final.

There was no control of damping-off by betanaphthol 4 gms., calcium sulfite 5 to 30 gms., calcium sulfate 15 to 45 gms., charcoal (wood, powdered) 25 to 100 gms., cupric carbonate 2 to 4 gms., naphthalene 20 to 40 gms., o-cresol 10 gms., pentachlorethane or tetrachlorethane 5 to 12 gms.

There was partial, but not always satisfactory control of damping-off by acetone 1:20, aluminum sulfate 30 but not 25 gms., ammonium acetate 40 but not 25 gms., ammonium sulfocyanate 8 but not 6 gms., calcium acetate 20 to 60 gms., calcium chloride 20 to 25 gms., calcium hypochlorite 12 to 16 gms., calcium sulfocarbolate 25 to 50 gms., metallic copper (powdered) 8 to 12 gms., copper acetoarsenite 2 to 4 gms., cuprous cyanide 1 to 4 gms., copper sulfate 3.5 to 5.5 gms., copper sulfocarbolate 6 but not 5 gms., copper-lime dust (80-20) 20 to 30 gms., potassium permanganate 30 to 50 gms., sulfuric acid (sp. gr. 1.84) 6 to 15 gms., zinc oxide 20 to 25 but not 15 gms., and zinc sulfate 10 to 16 gms.

Damping-off was well controlled by ammonium hydroxide 1:30 to 1:50 (but not 1:60), calcium cyanamide 12 to 16 gms., and raw pyroligneous acid 4:100.

Certain treatments injurious to some species were harmless or even beneficial to other species.

Growth of the following species was improved by the treatments indicated: *Campanula medium* and *Digitalis purpurea* by acetone 1:60 and 1:70; Dianthus (9 species) by aluminum sulfate 20 gms.; *Erysimum asperum*, beet, and cucumber by ammonium hydroxide 1:50 (10 days before seeding); *Reseda odorata* and beet by calcium chloride 15 gms.; *Brunnera macrophylla*, *Scabiosa atropurpurea*, *Alyssum argenteum* and beet by calcium cyanamide 10 gms. (10 days before seeding); sweet pea by calcium sulfate 20 to 30 gms.; *Verbena hortensis* by calcium sulfocarbolate 5 to 10 gms.; *Tropaeolum majus* by charcoal 25 to 100 gms.; *Althaea rosea* by cupric carbonate 4 to 6 gms. and by cuprous cyanide 2 to 3 gms.; sweet pea and *Ageratum Houstonianum* by copper sulfocarbolate 3.5 to 4 gms.; *Arabis albida*, *Gypsophila repens*, *Althaea rosea*, beet and cucumber by potassium permanganate 25 to 40 gms.; and *Lupinus polyphyllus* by zinc oxide 15 to 20 gms.

Apple Rust. (E. F. Guba, Waltham.) In cooperation with Dr. J. H. Faull of Harvard University, a small test was conducted to determine the effectiveness of fungicides in controlling apple rust (*Gymnosporangium juniperi-virginianae* Schw.) on Wealthy apple. The results indicate that sulfur fungicides have some value in reducing the amount of infection, but the best of the five materials tested, namely, liquid lime-sulfur and a colloidal paste called Linco, did not reduce infection more than 50 percent of that shown by the controls.

Plant Containers. (L. H. Jones.) An effort is being made to develop a plant container suitable for growing young trees and shrubs in nurseries. The adoption of pot culture in nurseries would lessen the care required in establishing the plant in its permanent location.

The non-toxic effect of copper containers was confirmed by using barley as an indicator plant. Barley is said to be susceptible to small concentrations of copper, the effect being noticed by the lack of formation of grain heads. Tests showed that the barley seed formed on plants grown in copper containers was not only viable but also produced good barley seed; i. e., seed of the second generation was not affected by the copper container in which seeds of the first generation were grown.

---

[3] For earlier work, see Mass. Agr. Expt. Sta. Bul. 305, pp. 19-21, 1934.

Absorption of Nutrients by Clay Pots. (H. D. Haskins and L. H. Jones.) Special clay pots without drainage holes were used to ascertain the amount of nutrients absorbed by clay pots in contact with soil. Empty pots on a bench soil absorbed more nutrients than soil-filled pots in glass saucers. Soil-filled pots kept fallow showed a greater gain in nutrients than similar pots containing plants. Evidently some of the nutrients that move from the soil to the pot may be recovered by a growing plant. Quantitative determinations were made in terms of nitrogen, phosphoric acid, potassium oxide, calcium oxide, magnesium oxide, and sulfates.

DEPARTMENT OF CHEMISTRY

W. S. Ritchie in Charge

The Effect of Fertilizer and Cultural Treatment on the Composition of Havana Seed Tobacco. (E. B. Holland and E. Bennett.) Havana seed tobacco has been raised experimentally on the station plots for many years and the web from the various grades of leaf has been analyzed for a sufficient portion of the time to establish positive trends. The results are being summarized and presented in a series of articles covering various phases of the investigation. The first two papers are entitled "Yield and Grades of Havana Seed Tobacco and Seasonal Influences" and "Analyses of Smoking and Cigarette Tobaccos." The immediate continuation of the project will depend on whether any aspects of the work appear to warrant additional study.

Nitrogen Intake of Havana Seed Tobacco in Relation to Nitrogen Synthesis and Quality of Leaf. (E. B. Holland and A. B. Beaumont.) This is a cooperative project with Agronomy and may be considered as embracing two distinct phases i. e., the effect of different amounts of nitrogen and of different forms of nitrogen on the yield and quality of leaf.

The total yield of cured leaf increased with the nitrogen applied, due largely to the increase in the size and weight of dark wrappers and to some of the seconds. The production of light and medium wrappers and long seconds reached the maximum on 164.50 pounds of nitrogen. Higher applications obviously increased the risk of producing a leaf of poorer burning qualities. Seasonal influences had a decided influence on the grades.

Systematic Study of Oil Sprays. (E. B. Holland.) The cooperative study with Entomology of the stability and effectiveness of various miscible oils in controlling orchard insect pests has been continued. In 1933 the miscibles were prepared from special oils containing more unsaturated hydrocarbons than those formerly employed, together with triethanolamine and oleic acid as the emulsifying agent. The oils were supplied by three different manufacturers. A portion of these miscibles, after standing a year, was applied the past season (1934) and proved equal in control to one of the best commercial products used as a standard and did not injure the buds or retard growth. In general a spindle oil requiring only a moderate amount of emulsifier seems preferable for spraying purposes.

The Copper, Iron, Manganese, and Iodine Content of Fruits and Vegetables Used as Human Foods. (E. B. Holland, C. P. Jones, and W. S. Ritchie.) One hundred and twenty-five samples of fruit and vegetables, suitable for human consumption, have been collected and prepared for analysis. The actual work of analyzing the samples has been started and will be continued through the coming year.

Absorption by Food Plants of Chemical Elements of Importance in Human Physiology and Nutrition. (A. B. Beaumont and E. B. Holland.) Under this cooperative project, Agronomy raises food crops under special fertilization to supply samples for the determination of copper, iron, manganese, and iodine in nutritional studies. Samples of spinach and turnips, fertilized with varying amounts of potassium iodide, have been taken and prepared for analysis. These samples will be analyzed during the coming year as part of the preceding project.

Cooperative Analytical Service. (The Department.) Additional cooperative investigations embrace a variety of substances and consume a great deal of laboratory time. Milk and eggs were analyzed for certain ash constituents. Additional samples have been taken to study "dark centers" in turnips. Iron and manganese were determined in greenhouse sands, for flower raising, in cooperation with the Waltham Field Station.

Testing Analytical Methods. (The Department.) The accepted methods for the determination of small amounts of iron, copper, iodine, and manganese in organic materials have been studied and adapted to the needs of the above investigations.

An electrically heated dryer with a forced circulation of air has been constructed during the past season for the preparation of fruit and vegetable samples at a moderate heat and has proved very efficient and time-saving.

Nitrogen Fixation in the Presence of or as a Result of the Growth of Legumes versus Non-legumes Under Certain Defined Agronomic Conditions. (F. W. Morse.) Alfalfa as the legume and barley as the non-legume were sown August 5, 1933, with the intention of continuing the alfalfa for at least two years. The alfalfa was not cut but was allowed to develop as much top-growth as possible for winter protection. The barley was also left to serve as winter cover for the soil and as a store of organic matter for the soil bacteria.

In the spring of 1934, the alfalfa was observed to have been nearly all winter-killed except a narrow strip along the western border of the plots where snow remained longest. The whole field was plowed and prepared for Hungarian millet which was planted on all plots. Nitrogen was withheld from Plots 5, 8, and 10. The results permit a comparison of the effects of leguminous residues with those of non-leguminous residues on the growth of a non-legume, Hungarian millet, together with the effects of the residual nitrogen from 1933 with that of the continuous withholding of nitrogen from Plots 6, 7, and 9. Hungarian millet was seeded on June 9 and cut on August 6, 7, 8, and 9 when in full bloom. During this period there was 6.88 inches of rainfall, which is one of the smallest in our records. The eastern half of the field is more moist than the western half. The millet following barley on the eastern half was superior to that following alfalfa, but on the drier western half the millet on alfalfa residue was superior. These differences observed throughout the growing period are definitely shown in the table of production of dry matter.

PRODUCTION OF DRY MATTER, POUNDS PER ACRE.

	Plots 5, 8, 10 With Residual Nitrogen*		Plots 6, 7, 9 Without Residual Nitrogen	
	Western Half	Eastern Half	Western Half	Eastern Half
Legume sections	4,051	3,988	4,267	3,937
Non-legume sections	3,395	4,729	3,343	4,349

NITROGEN IN SURFACE SOIL, PERCENT.

Legume sections	.139	.156	.137	.162
Non-legume sections	.149	.176	.145	.172

*Nitrogen at the rate of 45 pounds per acre was applied in 1933, and in the preceding years 1924, 1926, 1928, 1930, and 1932.

The plots with residual nitrogen were definitely ahead of those without it on the non-legume sections, but on the legume sections the residual nitrogen was without effect.

Hungarian millet was previously grown in 1932 as the non-legume. In that season the average production on the non-leguminous sections without nitrogen was 3464 pounds of dry matter per acre, and on the similar sections with applied nitrogen it was 5385 pounds of dry matter per acre. This year the average production on the eastern and western sections taken together was 3846 pounds of dry matter per acre without nitrogen, and 4062 pounds per acre with the residual nitrogen from previous applications. These two crops contained respectively 32.76 pounds and 36.59 pounds of nitrogen as determined by analysis of their samples. Application of 45 pounds per acre of nitrogen in 1933 and plowing under the crop grown upon it gave but 216 pounds more dry matter and 3.83 pounds increase in recovered nitrogen over the plots that have been without nitrogen or legumes since 1923.

Soil samples were secured from all the plot sections on August 23 and 24, representing the surface soil to the depth of 8 inches. Total nitrogen was determined in each sample. The results are tabulated in the same manner as dry matter in the crops.

The figures for the non-legume sections are positively higher than for the legume sections, showing no tendency toward exhaustion of soil nitrogen in the continued absence of legumes.

Chemical Study of Cranberries. (F. W. Morse.) A method for the determination of quinic acid in cranberries has been developed and applied to numerous samples of leading varieties.

Citric, malic, benzoic and quinic acids are found in the cranberry. A water solution of cranberry pulp or of cranberry juice is exactly neutralized with barium hydroxide. To the neutralized solution is added three times its volume of 95 percent alcohol. After thoroughly mixing the alcohol with the cranberry solution, the barium citrate and barium malate are precipitated, while barium benzoate and barium quinate remain in solution. Enough more alcohol is added to make a definite volume, as 250 cc. or any other convenient volume. The precipitate is removed by filtration and a measured volume of solution is used for quinic acid measurement by precipitating the barium with potassium sulfate. From the amount of barium, its equivalent quinic acid is calculated. Barium benzoate cannot be separated from the barium quinate. Benzoic acid may be determined by a special method in another portion of cranberry and deducted from the quinic acid percentage. Since no one has found more than .1 percent of benzoic acid in cranberries, and more commonly .05 percent is reported, one may deduct one of those quantities from the percentage of quinic acid calculated from the barium and be close to the truth for any sample of cranberry.

Leading varieties of cranberries analyzed by this method have shown the following percentages of quinic acid corrected by deducting .05 for benzoic acid.

	Percent
Early Black	.81 — .96
Howes	1.05 — 1.20
Centennial	.88 — 1.00
McFarlin	.91 — 1.00
Holliston	.74 — .86
Chipman	.82 — 1.02

These varieties constitute the bulk of the cranberries on the market as Cape Cod cranberries.

A Study of the Availability of Soil Potash with the Object of Developing a System of Diagnosis for the Soils of the State. (F. W. Morse.) The project has been brought to the final stage of preparation for publication as a bulletin. The soils of the State are naturally strong in potash, but vary widely in their ability to supply it to crops. Heavy, natural grass soils with normal rainfall do not respond to potash fertilizers. Light, easily tilled soils require additional soluble potash to reenforce the soil potash dissolved in the limited supply of water held by them.

Mineral Requirements for the Growth of Dairy Heifers. (J. G. Archibald and E. Bennett.) During the year the work in animal nutrition was transferred from the Department of Chemistry to the Department of Animal Husbandry. This change made available the much larger college herd for nutrition studies and involved the dispersal of the small experiment station herd and the conversion to other purposes of the building in which this herd had been housed. This project was therefore brought to completion and results from it will be published during the year.

Studies in the Chemistry of Pasture Grass. (J. G. Archibald and E. Bennett.) Results of a three-year study of the composition of six species of grass and one species of legume, all grown without fertilizer other than that residual in the soil, have been submitted recently for publication in the *Journal of Agricultural Research.*

The project was continued this season to note differential effects (if any) of a complete fertilizer on the composition of the several species. The work has been seriously interfered with this year by winter-killing and re-seeding difficulties, and it will be necessary to repeat it during at least one more season.

This project is now being conducted in cooperation with the Department of Animal Husbandry, due to transfer of the project leader to that department.

THE CRANBERRY STATION
(East Wareham, Massachusetts)

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Control of the Cranberry Root Grub (*Amphicoma vulpina*). Flooding to control this pest, described in the last two annual reports of the station (Bulletins 293 and 305) was tried on four different bogs this season with practically complete success on three and partial failure on the fourth.

Dust Insecticides. Extensive tests of dust mixtures containing high grade pyrethrum, low grade pyrethrum, rotenone, and nicotine were conducted to determine their relative value as controls for the blunt-nosed leafhopper and the blackheaded fireworm. The high grade pyrethrum mixture proved much more satisfactory against both these pests than the others, cost and effectiveness both considered. The nicotine dusts, though prepared especially for these tests by the chemists of a large corporation dealing in tobacco products, proved nearly worthless. The rotenone dusts were effective when used in sufficient strength and quantity, but they were much more expensive than the high grade pyrethrum mixture. Low grade pyrethrum was not very effective.

The Grape Anomala (*Anomala errans* Fab.[1]). Grubs of an unknown kind were found abundant in the turf of Mr. Royal Turner's bog in Sharon, Mass., on April 10 and May 10, 1934. They had very seriously damaged three or four acres of the bog by devouring the finer roots of the vines much as the cranberry root grub (*Amphicoma*) does. Large areas had become rather bare of vines on this account. Many of the grubs were dug out of the soil on May 10 and placed in sand in cans. Some of these cans were opened on June 1 and nearly all the grubs were found to have pupated. More of the cans were opened on June 15, and nearly all the pupae had then changed to beetles. Only one pupa remained, this being reddish brown and about a third of an inch long. It wriggled actively when disturbed. The beetles varied in color from pale yellow to black, the yellow ones being far more numerous than the darker forms. They could fly but did so but little. They were clever at feigning death and did so very often. They commonly proceeded to bury themselves in dirt or sand when they were placed on it. They would not eat cranberry or apple foliage but ate grape leaves very freely in confinement. On June 25, they were found to have laid many eggs in the sand in the cans in which they were confined. The eggs were scattered singly through the sand. They were milk white, smooth, shiny, oval, and about one and a half millimeters long. Some of the beetles were alive and some dead in the cans on July 2. All were dead July 6. The eggs had not begun to hatch July 6, many had hatched July 8, and all were hatched on the morning of July 9. There seems to be no record of a previous appearance of this insect as a cranberry pest. The infestation of Turner's bog was probably made easy by the considerable growth of grape vines around it.

The flooding treatment now advocated for the control of the cranberry root grub (see above) was applied and almost entirely eradicated the *Anomala* infestation.

The Chain-spotted Geometer (*Cingilia catenaria*). In July 1934, there was a serious outbreak of the caterpillars of this insect in Falmouth, Mashpee, Sandwich and Barnstable. It was most harmful in East Falmouth, Mashpee, the south part of Sandwich, and the west part of Barnstable. It was so severe in places in Sandwish, Mashpee and around Cotuit that all forest undergrowth was completely defoliated and turned brown. The worms were abundant for only a mile or two east of Hyannis and were not found much west of the main highway running from Bourne to Falmouth. They did considerable injury on some cranberry bogs around Waquoit and in Mashpee and seriously harmed some strawberry patches in East Falmouth. They usually defoliated withe-rod (*Viburnum cassinoides*) and wild indigo (*Baptisia tinctoria*), evidently being especially fond of them. The following plants were seriously attacked generally: Black huckleberry, dangleberry, scrub oak, willow, wild lupine (*Lupinus perennis*), beach plum (*Prunus maritima*), wild black cherry, and locust (*Robinia* sp.).

---

[1] Identified by H. C. Fall.
Generally named *Anomala lucicola* Fab. in entomological literature.

Datanas. Datana caterpillars were so abundant on small patches of a bog in Plympton that they defoliated the vines. They were fully grown on the bog on July 20, 1934. A lot of them pupated in confinement on July 30 and 31. The species was identified from the caterpillars by Mr. Carl Heinrich of the Bureau of Entomology, U. S. D. A., as *Datana drexelii* Hy. Edw.

COOPERATIVE CRANBERRY INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station

H. F. Bergman, Senior Pathologist, U. S. D. A., in Charge

Development of Strains of Cranberry Resistant to False Blossom. (H. F. Bergman and W. E. Truran.) Nearly 500 cross pollinations were made during the past season. These include Early Black x Shaw's Success, Centennial x Early Black, Paradise Meadow x Early Black, and reciprocal crosses between Early Black and McFarlin and between Shaw's Success and McFarlin. Although the season was very unfavorable, 25 to 50 percent of the pollinated flowers produced fruit. The best results were secured in crosses of McFarlin by Early Black, in which 48.4 percent of the pollinated flowers developed fruit. Only 24.5 percent of the flowers of Centennial pollinated by Early Black matured fruit.

Oxygen Content of Flooding Water in Relation to Injury to Cranberry Vines. (H. F. Bergman and W. E. Truran.) Observations were made on a number of bogs to determine the extent of injury to vines in relation to the depth of the winter flood. On some of these bogs the winter flood was let off in April and on others it was held until May 20 to 23. No differences were observed in the extent of injury to vines on bogs on which the water was held late as compared with those on which it was let off in April. The amount of injury is directly related to the depth of the winter flood, but depends also upon the character of water supply, density of vine growth, and amount of organic matter in the substratum. Injury ranged from mere retardation in development to death of a large proportion of terminal buds with severe defoliation. On one bog where the winter flood was held until May 23, 60 to 70 percent of the terminal buds were killed on the most deeply flooded areas where the water was 3 to 4 feet deep. On the same bog where the water was not more than 6 to 8 inches deep, only 3.3 percent of the terminal buds were killed. On plots in the most deeply flooded area, which had been sprayed with Bordeaux two or three times during the preceding summer, the vines came through in much better condition than the vines on adjacent unsprayed plots. Only 22 to 27 percent of the terminal buds on vines on the sprayed plots were killed and very little defoliation occurred.

Determinations of the oxygen content of flooding water in relation to bud and tip injury were made on a few bogs which were flooded in June. Low oxygen content of the water was found on one bog only. On this bog the oxygen content was below 1.5 mls. per liter over a period of 12 to 14 hours. On most parts of the bog flower buds were not sufficiently developed to be injured, but where more advanced about half of the buds were injured.

Regeneration of Bogs Infected with False Blossom. (H. F. Bergman.) About 0.2 acre of bog planted with Howes, with a moderate infection of false blossom and very weedy, was sprayed July 31 with a solution of sodium arsenite containing 8 pounds of this chemical dissolved in 100 gallons of water and applied at the rate of 1000 gallons per acre. Another part with an area of 0.3 acre was sprayed with a sodium arsenite solution of the same strength but containing 12½ pounds of sodium bisulfite per hundred gallons of solution. Both solutions killed vines and weeds down to the ground but failed to penetrate into underground portions and kill them. New growth from underground parts of cranberry vines and weeds was observed in September.

Spraying and Dusting Experiments. (H. F. Bergman and W. E. Truran.) Bordeaux made up by the 4-4-50 formula, with chemically hydrated lime, and applied at the rate of 350 to 400 gallons per acre was used on three bogs. Two mercurial sprays were used on one bog. Both mercurials were made up in two strengths: ½ pound and 1 pound to 50 gallons of water. The rate of application was the same as with Bordeaux. Only two applications of any of these sprays were made during the season. The amount of rot in berries from sprayed plots, with few exceptions, was reduced to half or less of that in berries from unsprayed plots. On one bog of Howes, two applications of Bordeaux had no apparent effect in reducing rots. The mercurial sprays reduced rots to about the same extent as Bordeaux.

An experiment on the use of mercurial dusts mixed with pyrethrum dust as a combined fungicide and insecticide was carried out in cooperation with Dr. H. J. Franklin. The mixtures were made up to give two different strengths of fungicide: one containing 1 pound of mercurial, 4 pounds of pyrethrum, and 9 pounds of gypsum; the other containing 2-4-8 pounds, respectively, of these ingredients. Two replications of two plots each were dusted with 7 pounds of dust of each strength for both mercurials. A check plot alternated with each dusted plot. The dust was applied June 21, at which time the earliest flower buds were just ready to open. Within two to three days after the dust was applied the leaves of vines on the dusted plots began to turn yellow. This was most marked on plots which had been dusted with mixtures containing two pounds of mercurial. The yellowing of the leaves reached a maximum in about a week, thereafter diminishing gradually, but was noticeable as late as September 1. On two plots, each dusted with two pounds of one of the mercurials, a considerable number of buds, flowers, young fruits, and tips of vines were killed. The yield of these two plots was reduced to one-third to one-half that of check plots. The amount of loss due to fungous rots in berries from plots which had been dusted with two pounds of mercurial was materially reduced as compared with that of berries from adjacent check plots. Some reduction in the amount of rot was effected by dusting with a mixture containing one pound of mercurial but this was not as effective as that containing two pounds.

Storage Tests of Cranberries. (H. F. Bergman and W. E. Truran.) The loss of berries from all plots which had been sprayed twice during the season, either with Bordeaux or with a mercurial spray, was only one-fourth to one-half that of berries from unsprayed plots up to December 1 to 15. Thereafter the difference in the amount of loss in berries from sprayed and unsprayed plots diminished due to the extensive development of late storage rots which had not been controlled by the two applications of spray. The amount of loss due to fungous rots in berries from plots which had been sprayed only once was not as great as that in berries from unsprayed plots but was greater than that in berries from plots sprayed twice.

An experiment to test the usefulness of a commercial preparation sold under the name of "Trioxo PH42"as a preventive of storage rots was also carried out. It is claimed by the manufacturers of this product that if cranberries are exposed to the gas liberated from it (formaldehyde) for 48 hours in a confined space, loss due to rots in storage will be prevented. Tests were made on 54 boxes of Early Blacks from the State Bog, of which 27 were treated with "Trioxo" as directed and the other 27 held as controls. After the treatment it was observed that many of the berries in the treated lot were injured. An examination of berries taken from the top and bottom of each of four boxes of the treated lot showed that the percentage of gas-injured berries at the top of three boxes varied from 20.0 to 23.4 percent, in the other box it was 11.1 percent; the injured berries at the bottom of the boxes varied from 0.5 to 2.0 percent. As a result of identification of fungi isolated in cultures made from 50 rotten berries from the treated lot and from 50 berries picked out from the controls, it was found that no difference existed either as to the kind or number of fungi present in berries of the treated and untreated lots. The berries were allowed to stand until December 19, when the final examination was made. The percentage of rotten berries in the treated lot varied from 16.7 to 27.7 with an average of 20.5; in the controls from 9.8 to 20.3 with an average of 14.6. In the treated lot the greatest amount of spoilage usually occurred in berries at the top of boxes, amounting to 25.0 to 45.0 percent. This was probably due mostly to the greater amount of gas injury as a result of higher gas concentration at these places.

Studies on Production and Dispersal of Spores of Fungi Causing Fruit Rots of Cranberries. (H. F. Bergman and M. S. Wilcox.) These studies have been carried on to secure information as to the probable time and method of infection of cranberries by rot-producing fungi in relation to the control of rots by spraying or other methods. The results are as follows. All the rot-producing fungi have been isolated from cranberry flower buds in all stages of development, even those much preceding the stage at which the first application of spray is made. The percentage of infected buds is greatly increased following a June reflow, and the increase is greater on unsprayed plots than on sprayed. The same fungi have been isolated from berries from the very earliest stages up to maturity. Differences in the percentage of infection of flower buds and of green fruits due to a particular fungus have been observed on different bogs and even on different plots on the same bog. The percentage of infected buds or green fruits is promptly reduced following an application of spray.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

A Method for the Determination of the Relative Stiffness of Cream During the Whipping Process. (W. S. Mueller.) The purpose of this study was to find a simple method for measuring the relative stiffness of cream throughout the whipping process and to show the importance of such measurements. It was found that, by the use of a mechanical whipper and sensitive wattmeter, a continuous record of the stiffness of the cream throughout the whipping process could be obtained by simply recording the input of the motor in watts at intervals of ten seconds, or less if desired. It was found that this method of measuring relative stiffness of cream could not be used with all mechanical whippers. The wattmeter method for measuring the stiffness of cream while it is being whipped should be useful in studies of cream whipping made either by the scientist or by the commercial dairyman. The results of this investigation have been prepared for publication in the *Journal of Dairy Science.*

Some Factors Affecting the Properties of Whipped Cream. (W. S. Mueller, M. J. Mack, and H. G. Lindquist.) This investigation was continued by studying the effect of the following factors:

1. Separation temperature.
2. Standardization with various dairy products.
3. Pasteurization temperature.
4. Homogenization.
5. Rate of cooling.
6. Addition of gelatin and other stabilizers.
7. Addition of sugar.

In the study of these various factors the keeping quality of the whipped cream received considerable attention as this is important to the dairyman selling cream already whipped. Further studies are necessary before any conclusions can be drawn.

Use of Gelatin in Ice Cream Specialties. (W. S. Mueller and J. H. Frandsen.) The results of this investigation have been published in *The Ice Cream Trade Journal* for July 1934. The following summary and conclusions were made:

1. The addition of fruit-flavored gels to ice cream specialties seems desirable from the standpoint of attractiveness, palatability, and greater variety.

2. Fruit-flavored gelatin will remain clear, even at ice cream storage temperatures, when the correct amount and kind of sugar is used in making the gel.

3. A gelatin-sugar mixture which contained 30 percent cane and 30 percent corn sugar proved most satisfactory.

Effect of Aging Treatment on the Bacterial Count of Ice Cream Mixes. (W. S. Mueller and R. L. France, Department of Bacteriology.) A report of this investigation has been published as Bulletin 314.

The Effect of Aging Treatments on the Tyndall Phenomenon of Gelatin-Water Solutions. (W. S. Mueller.) In this study gelatin-water solutions were subjected to the same aging treatments as the ice cream mixes (as reported in Bulletin 302) and the effect on the Tyndall phenomenon noted. It is hoped that these observations will aid in explaining the effect of the high (68°F.) initial aging temperature on ice cream mixes containing gelatin.

Stabilizers for High Fat Ice Cream. (W. S. Mueller.) Only a small amount of time has been given to this study during the past year. Some new or improved stabilizers appearing on the market are being tried out.

A Study of Ice Cream High in Fat Content. (M. J. Mack.) Work on comparatively rich ice creams, which are being sold in increasingly larger amounts, was continued throughout 1934. Previous studies revealed that when ice cream mixes of high fat content (18 and 20 percent fat) are made under usual processing conditions they are excessively viscous and produce crumbly ice cream with an undesirable melting appearance. The use of butter, frozen cream, or plastic cream in place of all or a part of the sweet cream needed to supply the butter fat markedly increases these three defects.

The use of three successive stages of homogenization entirely eliminates the problem of excessive viscosity and decreases the other defects already named. Pressures of 2,000, 500, and 150 pounds are suggested as satisfactory maximum pressures for the first, second, and third valves, respectively, when homogenizing an 18 percent butter fat mix. With a 20 percent fat content, somewhat lower pressures of 1500, 500, and 150 pounds are suggested as maximum pressures.

A crumbly body may be prevented in high butter fat ice creams by increasing the sugar content to 16 to 17 percent, depending somewhat on the fat content of the mix. If the use of cane sugar alone produces an excessively sweet taste, the substitution of corn sugar for 3 or 4 percent of the cane sugar is recommended.

Increasing the sugar content to 16 to 17 percent improves the melting appearance and reduces the melting resistance of high fat ice creams.

The use of three different stages of homogenization entirely eliminates excessively high viscosity which invariably occurs in chocolate ice cream mixes of high solids content.

The Utilization of Frozen Fruits in Ice Cream. (M. J. Mack and C. R. Fellers, Department of Horticultural Manufactures.) This project was revived after a lapse of two years to study more thoroughly the practice of slicing strawberries before freezing for later use in ice cream. About 500 pounds of whole and sliced frozen strawberries were furnished by the R. D. Bodle Company and Dr. H. C. Diehl of the United States Frozen Pack Laboratory, both of Seattle, Washington.

The frozen whole and sliced strawberries were thawed, examined, and used in ice cream. The practice of slicing the berries before freezing seems desirable. The packs consisting of sliced fruit contained less undissolved sugar than whole-fruit packs, showed less surface discoloration, contained firmer pieces of fruit of better flavor and color, and appeared to contain less syrup. To the fruit packer, slicing strawberries before freezing seems to be another means of improving his product.

Frozen sliced strawberries impart more flavor to strawberry ice cream than do frozen whole berries of the same run. However, the difference is not marked. Such factors as variety and degree of ripeness of the fruit and the sugar content of the pack were found to affect the flavor of strawberry ice cream to a greater extent than slicing the fruit before freezing.

Ice Cream Frozen Without Stirring. (M. J. Mack.) A large number of bulletins, pamphlets, and recipe books have been published which contain directions for freezing ice cream without agitation. These recipes are primarily designed for use with the electric refrigerator. Several commercial preparations are now on the market for use in making ice cream in the freezing tray of the home refrigerator. This project was organized with the purpose of studying ice creams frozen without stirring, as well as the various commercial preparations now available for use in ice cream of this type. Considerable progress has already been made in the study.

A Study of the Changes that Occur in the Storage of Frozen Sweet Cream. (H. G. Lindquist.) Cans of raw and pasteurized cream of varying fat content were frozen and stored at 0° to –10°F. for a period of 4 to 6 months. The raw cream developed more of the storage or tallowy flavor than did the pasteurized cream.

Subjecting cream to fast freezing conditions, such as freezing in a small ice cream freezer with the beater removed, appeared to partially prevent the fat from oiling off, when the cream was thawed after a storage period of 4 months.

Thawing cream slowly by immersing the cans in water at a temperature of less than 90°F. did not prevent oiling off when the cream was later pasteurized.

The work will be continued in an attempt to find a suitable means of preventing the oiling off of the fat when stored frozen cream is thawed.

A Study of the Comparative Efficiency of Electrically Operated Tanks versus Ice in the Cooling of Milk. (J. H. Frandsen.) During the year a study has been made of the comparative efficiency of a number of the newer electrically operated cooling tanks on the market, and of milk temperatures as affected by the water level in the cooling tank.

Presumably to hold down expenses, there is a practice on certain dairy farms where electric cooling units are used of not keeping the tank full of water when it contains only a half-capacity load of milk cans. Thus, for example, if the tank contains only the cans of evening milk and these cans are full, much of this milk is left above the water line until such time as the cans with the morning milk are placed in the tank next day.

To obtain definite information as to just what happens regarding the rate of cooling where some of the milk is above the water line, an experiment was planned whereby the temperature and samples for bacterial analysis of milk in all cans were carefully taken above the water line, at the water line, and near the bottom of the cans, as well as of the ice water in which the cans were immersed. These tests were made using a tank without agitator and also one with agitator, when the tank contained plenty of ice.

The results would indicate that the water in the tank should be as high as the milk line. This can be accomplished by the addition of more water to make up for the absence of some cans or by providing some arrangement whereby weighted empty cans may be placed in the tank so as to raise the water line to the height of the milk in the cans.

The results of this investigation are published in Department of Dairy Industry Circular No. 12, which contains graphic illustrations of the data gathered in the experiment.

A Study of the Possibilities of Milk, Cream, and Plastic Cream in the Development of New Products such as Combinations with Honey, Fruits, and Flavors of Various Kinds. (J. H. Frandsen and T. Marcus.) A few pieces of special equipment which can now be secured make possible the skimming of a specially rich sweet cream containing from 70 to 80 percent butter fat and generally known as "Plastic Cream." This plastic cream can be used as a basis for many delicious dairy spreads. Just now when dairy products are cheap and there is a surplus on the market seems the time to give them a trial in the home.

A mixture of 40 percent clover honey (heated to 142°F. for 30 minutes) and 60 percent of plastic cream testing about 80 percent butter fat was found popular. This mixture is easily prepared and keeps fairly well. In our opinion a little stick cinnamon placed in the hot honey for a few minutes adds to the desirability of the flavor. A combination of 57 percent plastic cream and 43 percent strawberry jam made a very good spread and was a favorite among many people who were consulted.

Although the above-mentioned spreads are well liked, other flavor combinations are more popular among some people. The best liked is a spread that might be termed a "plastic cream cheese-like spread." It is prepared by adding from 5 to 20 percent of lactic acid culture to the plastic cream spread, the mixing being accomplished while the cream is still soft and warm from the separator. Approximately 1 percent of salt is added. This finished dairy spread is then placed in a final package and held at a temperature of about 70°F. for 12 hours, after which it is placed in cold storage. Care should be exercised against the development of too much acidity. There seems to be a growing demand for sour cream products in our large cities, particularly those with foreign populations, and it is thought that this product will appeal to those nationalities who look with favor on acid-flavored products. The addition of 10 percent ground olives, pimentos, or sweet pickles adds a distinct flavor as well as aiding in masking the acid flavor. The ingredients of these various formulas are mixed with the warm cream direct from the separator, and the mixture is stirred until partly cool to prevent settling. The salt and other flavoring substances mentioned may be varied according to individual taste.

All the dairy spreads mentioned are easily made, keep fairly well, and provide something new and toothsome in the way of spreads for sandwiches, waffles, and biscuits, and should provide an additional outlet for some of our dairy products. The dairy spread can also be used in a variety of ways in cooking and baking and as a foundation for white sauce.

Department of Dairy Industry Circular No. 23 gives complete formulas and directions for the making of Honey Cream Spread, Strawberry Cream Spread, Strong Flavored Sour Cream Spread, Mild Flavored Sour Cream Spread, Olive Cream Spread, Pimento Cream Spread, and Cream Spread Relish.

Milk Drinks. In an effort to find and develop new uses for milk, several formulas for milk drinks were developed or collected. These have been published in Department of Dairy Industry Circular No. 21.

DEPARTMENT OF ENTOMOLOGY

A. I. Bourne in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne, and W. D. Whitcomb, Waltham.)

Oil Sprays for Scale and Red Mite in Orchards. The severe winter of 1933-34 with its long periods of very low temperatures necessitated changes in the season's program in most of the orchards in the State. Many growers who observed the extensive damage to their trees during late winter and early spring doubted the safety of following their usual program of delayed dormant applications of oil sprays, and chose to allow scale and red mite to go unchecked rather than face the possibility of further injury, by the application of the oils to their already weakened trees. Some growers, however, followed their usual schedule and applied the oil sprays, and it is worthy of note that no direct injury resulted nor was there any apparent increase in the winter injury due to the use of the oils. This was true of both the commercial petroleum oil sprays and the recently developed tar distillate washes.

In the tests at the college the number of overwintering red mite eggs was moderately large, and there was no significant winter mortality. Consequently the infestation that developed proved serious when unchecked.

The standard brands of commercial oil sprays, Kleenup, Sunoco, Peninsula Oil Emulsion, etc., gave their usual high degree of control. In addition a new type of soluble wool oil prepared by the Colonial Oil Company proved very effective in its first season's test, giving 98 to 99 percent control. Trees sprayed with this oil showed 88 percent of the leaf clusters free from young mites, and infested leaf clusters averaged 12 mites per cluster of 6 to 7 leaves as compared with 1,968 per cluster on the unsprayed checks.

Tar Distillate Washes for Overwintering Eggs of Plant Lice in Orchards. Field tests were made with six different types of tar distillate washes and one cresylic acid oil emulsion. These represent a new development in oil sprays and are designed primarily for use in *dormant* applications, for the control of overwintering eggs of different species of plant lice. The tar oils alone have not proved very efficient against European red mite so that many of the samples on the market today are a combination of tar oil emulsion and petroleum. The samples tested included the following:

Tar-Petro-Emulsion, Ansbacher-Siegle Corporation,
 a coal tar creosote–mineral oil combination;
Tar-O-Emulsion, Ansbacher-Siegle Corporation,
 a coal tar creosote oil;
Cres.-Emulsion, Ansbacher-Siegle Corporation,
 a mineral oil–cresylic acid combination;
Kleenup-Tar Oil Emulsion, California Spray Chemical Co.,
 a coal tar creosote oil with Kleenup;
Tarolene, Central Chemical Company,
 a coal tar creosote–mineral oil combination;
Tar Oil Wash, Niagara Sprayer and Chemical Co., Inc.,
 a coal tar creosote oil;
Tar E. Mul, Niagara Sprayer and Chemical Co., Inc.,
 a coal tar creosote–mineral oil combination.

In spite of the severe winter and the possible ill effects upon the trees, careful observation failed to discover injury following any of the above sprays nor was the seasonal development of sprayed trees retarded. The heavy winter mortality of the overwintering eggs of plant lice on these trees caused such an irregular and insignificant hatch on the unsprayed checks that no accurate results from the use of the oils could be obtained.

Rotenone and Pyrethrum Sprays for Gladiolus Thrips. In tests against gladiolus thrips Cubor spray gave excellent results. This is a rotenone compound in the form of a dry powder. Care must be taken to thoroughly dissolve the powder in water. Considerable agitation was necessary to do this; otherwise the material showed a tendency to collect into drops on drying, leaving large areas of the plant surface uncovered. However, if carefully prepared, this spray appeared to be one of the best of the rotenone group. Ku-ba-tox spray, another rotenone compound, gave fine coverage with no indication of the defects mentioned above. A combination of lead arsenate, molasses, and water caused no injury to plants and gave good control of thrips. Similar combinations in which Paris green and calcium arsenate were used to replace lead arsenate caused serious injury to the plants. Laboratory tests of different strengths of two rotenone sprays and one pyrethrum–rotenone spray against adult and young-stage thrips gave the following results:

Material	Adult Thrips		Young Thrips	
	Exposure (hours)	Percentage of Kill	Exposure (hours)	Percentage of Kill
Cubor . . . . . 1 lb.—50 gal.	24	60		
Ku-ba-tox 1—400	24	75	18	90
Cubor . . . . . 2 lbs.—50 gal.	24	100		
Ku-ba-tox 1—200	24	100		
Red Arrow 1—200	24	90		
Red Arrow 1—400	24	80	18	85
Red Arrow 1—400 +Dipest 1—400	24	100		
Kaloil . . . . . . 1—400			18	90

Rotenone Sprays and Dusts for Mexican Bean Beetle. Rotenone sprays and dusts both gave excellent control of larvae of the Mexican bean beetle. The sprays also gave a high percentage of kill of adult beetles. Although in many cases the killing action of the rotenone compounds was not as rapid as that of arsenicals, yet following rotenone applications the insects quickly ceased feeding and dropped to the ground and very few, if any, revived sufficiently to resume feeding. The value of rotenone compounds lies chiefly in the fact that these could be employed after an attack had developed and also could be applied much nearer the time of harvesting the crop than would be possible with arsenicals or fluorine compounds.

Wettable Sulfurs as Substitutes for Lime-Sulfur in Post-Blossom Orchard Sprays. Tests of these materials were continued in cooperation with the Department of Pomology. The tests in the station orchard were duplicated in a commercial orchard near-by. Five standard types of wettable sulfurs were tested in combination with lead aresenate, and their relative values compared with the standard combination of lead arsenate–lime-sulfur solution on both McIntosh and Baldwin. In the pre-blossom and calyx sprays, the lime-sulfur–lead arsenate combination was used. The wettable sulfurs were applied in the first, second, and third cover sprays, and lead arsenate alone in the fourth cover. In addition to the commercial sulfur sprays, a product composed of 300-mesh sulfur and a slight amount of wetting agent was used with lead arsenate in the first three cover sprays.

While on the whole the season was not of a type to induce severe burning and at the same time was not particularly favorable for scab, yet unmistakable and general burning of foliage was noted following the lead arsenate–lime-sulfur applications. No russeting of fruit was noted. The wettable sulfur sprays in no case caused any foliage injury following any of the three applications. The degree of control of insect pests and diseases from the use of these sprays was measured chiefly on McIntosh, a variety particularly susceptible to scab, and are as follows:

Treatment	Percentage of Clean Fruit	Percentage of Fruit Showing Injury From:		
		Curculio	Codling Moth	Scab
Apple Dritomic	88.2	4.0	5.7	1.1
Magnetic sulfur	91.7	3.0	4.3	0
Mulsoid sulfur	70.5	16.5	13.6	0.2
300 mesh sulfur + wetting agent	85.8	5.6	4.5	3.2
Sulcoloid	94.5	0.4	2.2	1.1
Lime-sulfur	78.1	1.3	15.7	3.5
Flotation sulfur	88.4	0.9	8.9	0.3
Check	10.4	52.0	34.4	50.4

All the products controlled scab very satisfactorily. In the summer sprays after the calyx, a casein spreader was added to the lime-sulfur–lead arsenate sprays. It should be noted that the commercial wettable sulfurs held scab to a lower figure than did lime-sulfur to which the spreader had been added. These results were also noted in the tests in the commercial orchards. Apparently the efforts to lessen the danger of burning from the lime-sulfur–lead arsenate combination also materially reduced its efficiency against scab. The combination of finely divided sulfur and wetting agent was not quite as effective against scab as were the commercial products but it gave very satisfactory control, and this product with lead arsenate held insect pests to as low a figure as did the more expensive commercial products.

Control of Striped Cucumber Beetle with Derris and Pyrethrum Dusts. When both commercial and home-made dusts containing the derris equivalent of .4 to .6 percent rotenone, and a pyrethrum–sulfur dust with a .05 percent pyrethrin content were applied directly to the beetles in the laboratory, all were dead or dying 4 hours after application. Copper–arsenate–lime dust (20-10-70) killed 60 percent of the beetles in 44 hours, while all untreated beetles lived 10 days or longer. When untreated beetles were confined with dusted plants, the dusts protected the plants from injury and the majority of the beetles were dead after 15 days. Copper–arsenate–lime was slow in becoming effective but was very satisfactory at the end of the experiment. Pyrethrum–sulfur dust was the least effective material. Undusted plants were killed in three days.

In the field 7 applications of these dusts were made to melons, cucumbers, and summer squash. Fresh applications of dust killed many of the beetles and protected the plants from injury until they were washed off, although the greatest interval between rains during this period was 5 days. Derris–sulfur dust and copper–arsenate–lime dust caused slight injury to melon vines during exceptionally hot weather, and this caused a slight decrease in the yield. Yield records of melons and cucumbers indicated that the application of these dusts did not noticeably interfere with pollination.

Control of White Apple Leafhopper with Pyrethrum and Derris Dust. A 20-80 pyrethrum–clay dust applied from both sides at the approximate rate of 1 pound per tree of medium size on August 30 reduced the second generation of the white apple leafhopper on McIntosh from an average of 18.66 per leaf to 3.07 per leaf.

On September 10 in another orchard where the infestation averaged 10.18 hoppers per leaf, an application of derris–pyrethrum–clay dust (10-15-75) reduced the average number of hoppers to 7.08 per leaf; derris–clay dust (12½-87½), to 4.21 per leaf; and pyrethrum–clay dust (30-70), to 2.16 hoppers per leaf. The number of dead hoppers per square foot on cloth spread under representative trees was: derris–pyrethrum dust, 10.45; derris dust, 45.43; and pyrethrum dust, 59.12. These trees were very large and required from 1½ to 2½ pounds of dust per tree for satisfactory coverage. It is apparent that a pyrethrum dust containing .2 to .3 percent pyrethrins gives better control than a derris dust containing .5 percent rotenone, but their practical and economical value is not yet determined.

Control of Squash Vine Borer with Oils, Soap, and Nicotine. In field experiments where the borer infestation in unsprayed Hubbard squash was 2.25 tunnels per vine, oil emulsions diluted to contain 2 percent oil failed to give satisfactory control and caused slight injury to the vines. Lead arsenate and nicotine sulfate combined with soap and pine tar soap (1 pound in 10 gallons of water) gave only moderate protection. A spray consisting of 1 percent white lubricating oil emulsion and 40 per cent nicotine sulfate 1-500 was most effective, showing 26 percent more reduction of borer than the standard treatment of 40 percent nicotine sulfate 1-250. This formula costs ½ cent per gallon less than the standard spray and promises to develop a practical value.

Control of Cabbage Maggot with Calomel Dust. When 4 percent calomel–lime dust was applied to 14 plats so that all possible combinations from 4 applications were made beginning May 7 when first eggs were found and continuing at weekly intervals, a single application at any of the treatment periods was not effective. Applications at the first and second intervals gave 82 percent commercial control of maggots and 88 percent large or medium heads. In general, two or more treatments which included the first and second applications were satisfactory but others were not. Of the untreated plants, 84 percent suffered moderate or severe injury, although 43 percent reached satisfactory size. Corrosive sublimate solution 1-1000 continued to prove its superiority and if applied when the eggs were first found yielded 80 percent commercially clean plants and 82 percent satisfactory heads. Three applications of naphthalene flakes were equally effective.

Applications of similar materials to radishes were less effective and although two applications of corrosive sublimate solution gave moderate control the plants were stunted by the treatment.

Control of Onion Thrips. (A. I. Bourne.) Thrips were late in appearing this past season and were much less abundant than for several years. There were few fields in the Valley that showed any appreciable injury by these insects, although the hot weather and long period of drought in midsummer offered conditions very favorable for thrips. In the experimental plots the average number of thrips per plant did not reach 20 until July 16. Their numbers reached the peak of abundance July 30 to August 1 and dropped rapidly from that point. Set onions did not show a heavy infestation, so that as they matured the migration of thrips to seed onions was not serious. This condition was unusual in a summer so hot and dry as that of 1934.

None of the sprays or dusts used in the field tests gave as high a degree of control as did the nicotine sulfate-soap combination, although rotenone sprays (Ku-ba-tox) proved nearly as effective and appeared to have a considerable residual effect which prevented rapid reinfestation. Grandpa's Wonder Pine Tar soap proved fully as efficient a spreading and wetting agent as fish oil soap, although its cost is higher. Rotenone dusts and a pyrethrum dust did not give as good control as sprays, due chiefly to the mechanical difficulties in forcing a dust into the tight axils of the inner leaves where most of the thrips are located. A combined spray of nicotine sulfate and wettable sulfur gave only moderate control, the sulfur proving inferior to soaps as a spreader and distributing agent.

Because of the mechanical difficulties involved in applying insecticides for the control of the onion thrips and also because of the fact that a resistant strain of onions would probably offer an excellent means of control of this pest, investigations were begun on several thrips-resistant varieties of onions this year. Through the courtesy of investigators at Cornell University, six varieties of onions were secured, including Utah Experiment Station Sweet Spanish, Winegar Strain Sweet Spanish, Harris 597 Riverside Sweet Spanish, Harris No. 58, Ohio Yellow Globe, and Ebenezer. The onions were planted in 13-inch rows about May 15. Due to the late development of thrips, counts were taken first on July 16 and at weekly intervals thereafter. The average number of thrips per plant is recorded in the following table.

Variety	Average number of thrips per plant					
	July 16	July 23	July 31	Aug. 6	Aug. 14	Aug. 20
Utah Exp. Station Sweet Spanish	14.2	18.6	14.6	9.0	13.0	14.0
Winegar Strain Sweet Spanish	4.2	12.4	12	9.2	12.0	15.4
Harris No. 597 Riverside Sweet Spanish	10.4	14	23.4	14.0	18.0	49.0
Harris No. 58 Prizetaker	17	20.6	53.6	35.4	47.0	41.0
Ebenezer or Japanese	23.6	44.4	77.8	52.0	62.0	71.0
Ohio Yellow Globe	14.4	40	74.4	57.6	91.0	70.0

It is quite apparent that all of the Sweet Spanish type of onions consistently showed the smaller number of thrips. The population curve of the Ohio Yellow Globe was very similar to that obtained over a period of years for the Danvers Yellow Globe so commonly grown here in the Connecticut Valley.

The type of growth of the different varieties would appear to have a direct correlation with the abundance of thrips. The varieties Ohio Yellow Globe and Ebenezer, both of which show a marked susceptibility to thrips injury, seem to offer the most favorable condition for protection of the thrips from adverse conditions. In the case of the variety Ebenezer, it was noted that the leaves have a strong tendency to curl, thus offering much more protection to the thrips than the markedly upright type of growth shown by Winegar Strain Sweet Spanish. The type of growth in the variety Ohio Yellow Globe is such that the growing tip (the chit) is more or less completely enclosed by the older leaves. In some strains grown by the Department of Agronomy of this station, it was noted, in an examination of three strains which otherwise had the same characteristics, that two of the three plots had an open chit. The average number of thrips per plant for these plots was as follows:

Date	Plants with Open Chit		Plants with Tight Chit	
	Plot	Average number of thrips	Plot	Average number of thrips
Aug. 1	B1+B2	16	B3	103
Aug. 8	B1+B2	26	B3	95
Aug. 14	B1+B2	40	B3	119

From these data it would seem that the open type of growth is a character to be sought for in breeding strains of onions resistant to thrips. Whether or not the character of an open chit is of value in a thrips-resistant strain, however, it is apparent that this type of growth is desirable if the thrips are to be controlled by either a dust or a spray. With the open type of growth, the growing tip (where the majority of young thrips are usually found) can be kept covered with an insecticide much more readily than can the chit which is partly or completely enclosed by the older leaves. It would appear from the above figures that if the varieties were of equal commercial value the resistant strains, such as the Sweet Spanish types, would do much to solve the problem of thrips control.

The disease attacking thrips, which was so prevalent in 1932 and to a lesser degree in 1933, again appeared in considerable abundance throughout onion fields in the Connecticut Valley. The relative scarcity of thrips and the severe check to the seed onion crop caused by the prolonged drought did not allow it to develop as rapidly as in the more favorable season of 1932. Attempts are being made to produce cultures of the fungus, with the hope of introducing it artificially in onion fields so that its presence would coincide more nearly with the peak of thrips abundance.

The Spray Residue Problem. (A. I. Bourne.) The limits of tolerance of both lead and arsenic residue on sprayed fruit at harvest were still further reduced for the shipping season of 1934, with the immediate prospect that within one or two years the final limits of .014 grains per pound for lead and .01 grains per pound for arsenic would be required.

Through the cooperation of the State Office of the Food and Drug Administration, analyses were made for both lead and arsenic on samples of McIntosh and Baldwin, to determine the latest point in the present spray schedule when fruit can be sprayed with reasonable assurance of safety and beyond which the danger of residues over the tolerance is encountered. Samples of fruit as taken from the orchard, samples which had been run through a commercial wiping machine, and samples which had been subjected to washing in an acid bath were submitted for analyses. The results of the analyses are as follows:

Last Spray	McINTOSH Spray Residue—Grains per Pound		BALDWIN Spray Residue—Grains per Pound	
	Arsenic	Lead	Arsenic	Lead
	Orchard-run Fruit			
1st Cover......	Trace	.004	Trace	.002
2d Cover.......	.006	.017	.002	.016
3d Cover.......	.008	.018	.008	.018
4th Cover......	....	....	.008	.019
	Wiped Fruit			
1st Cover......	.002	.005	Trace	.005
2d Cover.......	.004	.017	.003	.013
3d Cover.......	.006	.016	.004	.007
4th Cover......	....	....	.008	.019
	Fruit Washed in Acid Bath			
1st Cover.......	Trace	.002	Trace	.002
2d Cover.......	.002	.004	Trace	.005
3d Cover.......	Trace	Trace	.002	.003
4th Cover......	....	....	Trace	.003

The analyses indicated that in a summer such as 1934 McIntosh could not be sprayed later than mid-July without showing undue amounts of arsenic, and that lead residue was excessive on fruit sprayed in mid-June. Because of the persistence of the lead residue, Baldwins were in approximately the same position. Wiping the fruit gave no appreciable relief in the case of either variety, although the amount of visible residue on wiped fruit was noticeably less, and this treatment resulted in a marked improvement in appearance and finish. Samples treated to an acid bath in a washing machine were in all cases so cleared of spray residue that even when the complete schedule of four cover sprays (the last one applied in late July) was followed, the fruit showed only traces of either lead or arsenic.

The season of 1934 was particularly favorable for the retention of sprays on fruit and foliage. Throughout June, July, and early August the rainfall was unusually light and there were no hard driving rains to wash the spray materials from the fruit. Throughout September and early October the rainfall was heavy and consequently late varieties showed somewhat less residue. In a season of more normal rainfall in late July and August the danger from the third cover spray would be materially lessened.

Results of the present season's tests show that lead is much more persistent than arsenic and constitutes the real problem. Lead residues were in many cases three to four times those of arsenic and were almost always higher than the ratio of lead to arsenic in lead arsenate. It is evident that running fruit through a wiping machine does not remove sufficient residue. Apparently the brushes become more or less covered with the spray material and consequently may transfer the residue from one sample to another. This was definitely proved in the case of a sample of fruit which, although sprayed with calcium arsenate throughout the season, nevertheless showed .002 grains per pound of *lead* present after being passed through the wiper. Frequent cleaning or replacement of the brushes would be necessary to avoid objectionable accumulations of spray material. Greater emphasis on reduced dosage in the late cover sprays or the substitution of a dust schedule for the late application offers the best solution of the difficulty as long as lead arsenate continues to be used.

Systematic Study of Oil Sprays. (A. I. Bourne in cooperation with the Department of Chemistry.) The three oils used in the 1934 field tests were samples which had been prepared the previous season and held in storage for approximately a year. The results obtained furnished data on the insecticidal value of these oils and also demonstrated their stability. All the samples were found to be in perfect physical condition, with no trace of breakdown of the emulsion. They offered no difficulty in preparation and showed no trace of separation and appearance of free oil when once diluted with water. They were applied, at a strength of 3 percent basic oil, to a block of young plum trees heavily infested with overwintering eggs of European red mite, at the delayed dormant stage of bud development. No trace of injury was noted nor was any check to seasonal development observed. All the samples proved very effective against red mite, as shown in the following table.

Sample	Percentage of Clusters Free from Mites	Number of Mites per 100 Leaf Clusters	Percentage of Control
F	85	15	98–99
G	80	36	98
H	77	33	98+
Check	0	1,968	—

Apple Maggot Control. (A. I. Bourne.) The appearance and seasonal abundance of the insect were watched with considerable interest throughout the season to note the influence of the severe weather conditions of the previous winter upon the insect and the effect, upon the infestation in commercial orchards, of the extensive CWA program of removal of neglected trees in pastures, fence rows, etc., closely adjoining such blocks.

Efforts were continued to stimulate community action on the part of growers within well-defined maggot control areas. Results again demonstrated the difficulty of securing concerted action on the part of all the growers in any large area, and that failure of any grower to carry out his assignment not only led to failure to control the insect in his own orchard but did much to neutralize the efforts of neighboring growers.

There were several orchards where apple maggot appeared the past season for the first time as a serious pest, in spite of thorough and supposedly well-timed spraying. In most of these cases the trouble was directly attributable to the removal of large numbers of neglected trees adjoining the orchards. Fruit from these trees was badly riddled by maggot the previous season and led to the appearance of thousands of flies which necessarily moved into the commercial orchards. In cases of such wholesale removal of neglected trees, it is essential that in commercial orchards the complete spray program be carried out, at least for the first season. Disposal of such trees, however, removes permanently a very serious source of danger.

In general there were three main factors which tended to increase the danger of infestation of fruit in commercial blocks.

1. A short crop, especially of Baldwins, due to winter injury and to the heavy Baldwin crop of the previous year.
2. The CWA project of removal of neglected trees adjoining orchards.
3. The tendency on the part of many growers to apply a complete spray program only to the trees in fruit.

A combination of any or all of these factors rendered the control of apple maggot particularly difficult this past season. Most of these, however, were peculiar to the past season and would not normally be expected to exert so much influence in 1935.

Valuable data on the influence of different soil conditions and of exposure upon the emergence of the adult flies were secured from cage experiments at the Waltham Field Station by Professor Whitcomb. These are summarized as follows:

Date of Emergence of Apple Maggot Flies, Waltham, 1934

	In Sun		In Shade	
	Cultivated	Sod	Cultivated	Sod
	Light Soil			
1st fly	June 22		July 3	July 6
25% flies	July 9		July 15	July 16
50% flies	July 15		July 20	July 22
75% flies	July 18		July 25	July 27
	Heavy Soil			
1st fly	July 1	July 14	July 9	July 10
25% flies	July 16	July 23	July 20	July 23
50% flies	July 19	July 26	July 24	July 26
75% flies	July 22	July 29	July 28	July 30

These results show the difference to be expected in the emergence of the flies in cultivated orchards and those in sod, and in heavy soil as compared with light. Flies appeared earlier from soil exposed to direct sunlight than from soil in shade. These figures do much to explain the very uneven appearance of flies in commercial orchards because of the removal of near-by neglected trees during the previous winter and consequently the extended period during which fruit was exposed to infestation.

Introduction of Parasites of Oriental Fruit Moth. (A. I. Bourne.) Through the cooperation of the Federal Bureau of Entomology the program of introducing larval parasites of the oriental fruit moth was continued throughout the peach-growing sections of the State. The extremely low temperatures of the winter resulted in a total loss of the peach crop throughout the State. This, however, offered a rather unique opportunity to combat the fruit moth. Although the fruit buds were killed and the chances of a crop were destroyed, a very considerable percentage of the insects which attack the fruit survived and were forced to remain in the twigs even in late summer when normally they would have entered the fruit. Their failure to find fruit in which to develop in itself led to a heavy mortality of the fruit moth larvae, while the extended period of twig infestation gave better opportunity for the larval parasites to attack the pest.

More than 18,000 larval parasites (*Macrocentrus*) were liberated in the State during early July, and in addition many growers purchased colonies of the egg parasites to release in their orchards.

Twig collections showed a very considerable winter mortality of the parasites, especially in orchards where colonies had been released for the first time the previous summer. In Hampden County, where the work of introducing parasites had been carried on for several years, and where they are becoming well established, the percentage of survival was higher.

Late summer twig collections showed parasites again building up successfully. In the western counties, records of 70 to 90 percent parasitism were made in orchards where releases had been made for several years in succession; and of 45 to 70 percent where colonization had been attempted for shorter periods. In the eastern orchards, where the parasites had been reduced to very low numbers by winter mortality, the degree of parasitism was found to average 20 to 30 percent in the larger orchards, while in some of the smaller orchards it ranged from 50 to 70 percent.

Potato Spraying Experiments. (A. I. Bourne.) In appreciation of the present interest in potato growing, in western Massachusetts especially, and of the annually increasing acreage devoted to that crop, field tests of various insecticides were begun the past summer for the control of the more outstanding insect pests attacking that crop. Two types of rotenone sprays and dusts, a pyrethrum dust, and a commercial preparation containing calcium arsenate and a small amount of calcium arsenite, were tested in a complete season's program of weekly applications from early June, when the plants were but two to three inches high, through September when many plants had reached a length of nearly four feet. The variety grown was Green Mountain.

The different materials were used in combination with 5-5-50 Bordeaux, in all applications from June to late August, after which time flea beetles had passed their second peak of abundance and any danger of aphid or leafhopper attack was past. From late August to October five applications of Bordeaux mixture alone were made. The vines continued growing until mid-September, and remained green until killed by frost on October 9. The plots sprayed with the calcium arsenate–arsenite combination were the only ones where any injury to vines was noted. Plants in these plots began to show injury by late July and were dying down in considerable numbers by mid-September.

Against flea beetles, all the rotenone products gave excellent protection. They appeared to exert a considerable repellent effect in addition to their direct killing action. The sprays were slightly superior to the dusts. The pyrethrum dust was effective for a short time after application but appeared to have very little residual effect. No opportunity was allowed for the development of any aphid or leafhopper infestation in the rotenone or pyrethrum plots, but in order to control incipient attacks of aphids nicotine sulfate had to be added in two applications of the Bordeaux mixture in those plots where Bordeaux alone had been applied.

Excellent yields were secured in all the plots and particularly in those where rotenone compounds had been applied. The yield record of the different plots is as follows:

Material	Yield (Bushels per Acre)
Cubor spray (rotenone)	647.99
Cubor dust (rotenone)	579.
Ku-ba-tox spray (rotenone)	573.75
Ku-ba-tox dust (rotenone)	601.38
Pyrethrum dust	489.57
Calcium arsenate–arsenite mixture	519.12
Bordeaux mixture	560.3

The high yields in the rotenone-treated plots confirmed the superior appearance of the plants in those plots throughout the season, and indicate the correlation between heavy yields and the protection of the growing plants from diseases and insect pests.

Value of Electric Light Traps against Orchard Insect Pests. (A. I. Bourne.) During the past summer, through the cooperation of the New England Rural Electrification Committee and the Western Counties Light and Power Company, this department began a series of tests with electric light traps at the Bay Road Fruit Farm orchards in South Amherst.

Five bulb and pan and five electrocutor traps were installed in parallel rows. Electric power was supplied from wires running from a take-off from the main power line at the edge of the orchard. On the outer pole was placed an automatic time clock, fuse-box, and cut-out switch, and on the pole in the orchard was placed a recording thermograph. The electrocutor traps consisted of a 75-watt bulb suspended inside of a screen charged with about 1100 volts from a transformer in the top of the trap. Beneath the circular screen was suspended a wire basket to catch the insects which were electrocuted while flying through the charged screen toward the light. The bulb and pan traps consisted merely of a 75-watt bulb suspended over a pan of water, the surface of the water acting as a reflector to which the insects were attracted and drowned.

The lights were operated from June 18 until August 28, under control of an automatic time clock in series with the power line to the traps. The lights were on from one-half hour before sunset until about one-half hour before sunrise, corresponding to the flight period of the insects present in the orchard. Lights were turned off on rainy nights when insect flight was very slight. Each day the insect catch of the night before was counted and identified. A total of 42,857 insects was counted and identified, of which 1,498 were beneficial species. Orchard pests were counted as follows: codling moth, 321; apple tent caterpillar, 684; forest tent caterpillar, 52; bud moth, 43; cherry leaf roller, 35; plum curculio, 1; and apple maggot, 1. These numbers are undoubtedly only indicative of the actual numbers caught in the traps as the electrocutor traps completely burned the insects entering them.

The primary purpose of the experiment was to determine the relative numbers of codling moth, the time of emergence, and the possible control of the pest by means of the light traps. Seasonal catches of this insect showed that the stragglers from the first brood were present in the orchard until July 14. The second brood appeared a few days later and reached a peak of moth emergence on August 10, then receded slowly to the last night the light traps were operated, August 28. A comparison of these figures with emergence cage figures in 1924 (Massachusetts Agricultural Experiment Station Bulletin No. 233) shows that emergence from the cages was a few days slower than in the orchard, as indicated by the light traps, making allowance for any differences in seasonal emergence in the two years in which the records were taken. This seems to indicate that the light traps are perhaps more valuable than the emergence cages in determining the correct timing of orchard sprays for codling moth control, and that their chief usefulness lies in the accurate data they furnish on the seasonal abundance of the insect rather than in its actual destruction.

Counts of all kinds of insect injury on McIntosh apples in the orchard gave the following results: The row of electrocutor traps had 93.1 percent clean fruit while the bulb and pan row had 92.5 percent clean fruit. On the unlighted row adjoining the first-named row 95 percent was clean, whereas the third row adjoining contained 86.1 percent clean fruit. Codling moth injury in the row trapped by the electrocutor traps was .4 percent and in the row trapped by the bulb and pan traps, 1.35 percent. In one row adjoining the first-named traps injury was 2.9 percent; in the third row adjoining, 7.5 percent. Band catches of codling moth larvae furnished a definite indication of the value of light trapping. In the electrocutor trapped row 21 larvae were caught in the bands, whereas 19 were caught in the bulb and pan trapped row. A ring of 12 trees in a circle one row outside the two light rows contained 160 larvae, while the circle formed by 22 trees in the third row outside the lighted rows contained 537 larvae. In the 44 banded trees, 737 larvae were present, even after the regular spray and dust schedule.

As an aid in the supplementary control of orchard pests when combined with the regular spray program, as a means of timing the spray schedule according to the emergence of the different orchard pests, and as a means of securing a record of the occurrence of the various insects both harmful and beneficial, insect light traps seem to have a value to the commercial fruit grower.

Apple Leaf-Curling Midge. (W. D. Whitcomb, Waltham.) The early infestation by the apple leaf-curling midge (*Dasyneura mali* Kieffer) in 1934 was heavy, but midsummer drought and decreased leaf growth reduced the abundance of the later generations below that of 1933. No new infestations were discovered outside the area established last year.

At Ipswich, emergence and oviposition by the first generation began about May 25 and continued to June 8, the first larvae hatching about June 1. Maggots emerged from rolled leaves from June 19 to about July 1, and adults of the second generation were present from July 3 to 15, laying eggs from which mature maggots developed July 27 to August 3. After this date no regular cycle was noticeable but scattering infestations developed irregularly until October.

Population counts on representative infested trees showed an average of 345.7 eggs per bud, an average of 277.4 maggots per bud in rolled leaves, an average of 484 infested tips per small tree, and an average of 174.66 to 361.8 maggots per square foot collected under the tree. Since most of the trees spread 80 to 100 square feet, the estimated number of maggots is 15,000 to 25,000 per tree.

For the first time it was observed that some of the maggots crawled down the branches and trunk of the trees and spun cocoons under the bark and in crotches rather than dropping to the ground. This migration down the tree took place mostly during rain, partly because the rain softened the rolls and facilitated emergence and partly because they were not exposed to hot sun and dry wind at that time. After the maggots have become mature, their emergence is greatly influenced by rain. Only a small number of the maggots appear to transform into the succeeding generation, and the majority hibernate.

Practically all infested leaves dried and fell before August 10.

Cyanogas and naphthalene applied under the trees as soil insecticides reduced the number of adult midges collected in cloth cages from 11.5 to an average of 1.83 per square foot, but in spite of this reduction, migration and emergence from cocoons on the tree produced a heavy infestation on the treated trees.

Sprays containing sulfur, nicotine, and rotenone killed exposed eggs and newly hatched maggots in the laboratory but when applied to infested potted apple trees the results were disappointing.

Plum Curculio. (W. D. Whitcomb, Waltham.) The practical application of the relation of temperature to control of the plum curculio by spraying was attempted by spraying one row of heavily infested trees with lead arsenate and fish oil each second day for twelve days beginning May 22, four days after the calyx application. Based on the maximum daily temperature, the most timely sprays would have been applied May 27 to 29. The results showed that, except in one row which yielded only 81 apples, the amount of curculio-injured fruit decreased regularly from 48.92 percent on May 22 which was too early, to a minimum of 18 percent on May 28 which was the estimated most effective date, and again increased to 44.66 percent on June 1 which was too late for satisfactory protection.

Adaptability of Cryptolaemus to the Control of Mealybugs in the Greenhouse[*] (W. D. Whitcomb, Waltham.) After having practically eliminated a heavy infestation of the citrus mealybug in the greenhouse of the Waltham Field Station soon after being introduced, the colony of the mealybug predator, *Cryptolaemus montrouzieri* Muls., nearly died of starvation; but the few survivors developed in sufficient numbers to keep the pest under commercial control without the aid of insecticides for eighteen months, and they are now in a position to accomplish practical control of the mealybug whenever the pest should increase.

Introductions of this predatory insect were supervised in two commercial greenhouses, one growing gardenias infested by the citrus mealybug, *Pseudococcus citri* Risso, and the other growing chrysanthemums infested with the Mexican mealybug, *Phenacoccus gossypii* T. & Ckll. In both cases control almost to the point of eradication resulted when a second generation of the ladybird larvae developed. In each case, however, the mealybug developed so rapidly during the inactive and developmental periods of the ladybird beetles that considerable injury resulted to the plants or the use of insecticides was necessary before the predators controlled the pest.

These records show definitely that both *P. citri* and *P. gossypii* can be practically and economically controlled by *Cryptolaemus montrouzieri* when the beetles are properly manipulated, and that the successful establishment of these beetles is dependent on, (1) the comparative rate of reproduction of the pest and the predator, (2) the abundance of the pest at the time of introduction, (3) the number of predators introduced, (4) the season when the predators are introduced as it affects the relation of temperature to development, and (5) the type of plants infested by the mealybugs.

Naphthalene as a Fumigant for the Control of Greenhouse Insect Pests. (W. D. Whitcomb, Waltham.) When naphthalene was used in experimental fumigations at a rate of 2 ounces per 1000 cubic feet for 6 hours, the vaporization of the total amount in the first 3 hours and none in the last 3 hours killed 85 percent of the red spiders in a 3-hour exposure; three-fourths of the total amount in the first 3 hours and one-fourth in the last 3 hours killed 85 percent in a 4-hour exposure; and the total amount in 6 equal hourly applications required an exposure of 5 hours to kill 85 percent or more of the red spider.

These experiments indicate that an exposure of at least 3 hours to an atmosphere saturated with naphthalene is necessary to cause an appreciable mortality of red spider, and since saturation exists when 0.64 ounces of naphthalene are vaporized in 1000 cubic feet of air at 77°F., it is apparent that about twice as much vapor is lost and absorbed as is retained in the air during a 6-hour fumigation.

A homemade naphthalene fumigator has been developed in which warm air is blown over trays of naphthalene crystals by an electric fan. The air is heated to 165°F. by being blown over a resistance heating unit, and the dosage is regulated by the amount of crystals in the trays or by the time the apparatus is in operation. Experimental fumigations with this apparatus indicate that sensitive plants are less likely to be injured than when the application is made with lamps.

Typical injury in the form of blindness which occurs in some varieties of chrysanthemums following naphthalene fumigation appears to occur only during the bud formation stage, and buds which have developed to 1/8 inch diameter or larger are not blasted or otherwise injured by the treatment. In addition to the standard varieties which have been susceptible to this type of injury, Yellow Frost, Garnet King, Olivette, and Pride of Tokio were found to be moderately susceptible this year.

Biology and Control of the Carrot Rust Fly. (W. D. Whitcomb, Waltham.) The field infestation of the carrot rust fly in 1934 was closely related to the weather. Dry, hot weather in early summer was so unfavorable to the development of this pest that early planted carrots were practically uninjured while late planted carrots which were exposed to the favorable cool, wet weather of late August and September suffered from 10 to 27 percent moderate and severe injury.

It was apparent from control experiments that seed treatments with calomel mixed in varying quantities with inert clay are not active long enough to give protection from the attack of the second or third generation, even though they have shown many beneficial results on the early plantings.

Influence of Temperature on Development and Control of Red Spider. (W. D. Whitcomb, Waltham). Preliminary studies of the influence of temperature on the effectiveness of sprays used for combating the red spider have shown that the number of spiders killed usually varies between 60° and 80° F., and that this difference may be as great as 60 percent. The effectiveness of some materials varied directly with the increase in temperature and others inversely. Out of 34 materials or types of materials so far observed, 16 were consistently more effective at 60° than at 80°.

Heavy lubricating oil emulsions were more effective at the higher temperature probably due to the greater spreading and penetrating action, while light oil emulsions were distinctly superior at 60°F., evidently due to suppressed volatility and longer contact. Soaps were rather inconsistent in their response to temperature but showed a tendency toward greater effectiveness at 60°. Soluble sulfurs as represented by liquid lime-sulfur and carbon disulfide-sulfur emulsion were increasingly effective as the temperature increased, while the suspended sulfurs such as colloidal and wettable sulfur were more active at 60°.

Pyrethrum extracts showed a very decided decrease in effectiveness as the temperature was increased and although the concentrate contained approximately 2.15 percent pyrethrins the resulting kill of red spider was surprisingly low.

Extracts of derris containing about 1 percent rotenone showed a definite increase in effectiveness at the higher temperatures and when diluted 1-200 gave excellent control of red spider. Combinations of pyrethrum and derris reflected the influence of the derris by producing an excellent control with increased effectiveness at 70° and 80°F.

Additional studies showed that apparently the water miscible solvent used with pyrethrum and derris extracts, either alone or in combination, influenced the effectiveness. In preliminary experiments extracts in camphor oil, acetone, and alcohol were most effective in the order named.

DEPARTMENT OF FARM MANAGEMENT

R. L. Mighell in Charge

Bank Service Charges and National Recovery Policy. (R. L. Mighell and R. H. Barrett.) A stormy chapter in NRA history was terminated on November 28, 1934, when Article VIII containing the rules governing fair trade practices was deleted from the Bankers' Code of Fair Competition by official amendment. This marked the end of a year-long controversy over bank service charges and definitely removed the NRA from the field of price-fixing for bank services. Article VIII had provided that clearing house associations should adopt, subject to the approval of the Administrator, rules fixing uniform service charges "whereby services rendered by banks shall be compensated for either by adequate balances carried or by a scale of charges."

The Banking Code Committee of the American Bankers' Association originally set January 1, 1934, as the effective date for such uniform schedules of charges throughout the nation, and in December 1933 preliminary announcements of the new charges were sent to customers by some banks in Massachusetts and elsewhere.

An early part of this study consisted in a rapid examination of the schedules of charges thus announced. This analysis indicated that such a program if permitted to become universal might have dangerous deflationary effects. The increased charges particularly on small accounts seemed likely to lead to many withdrawals, increased hoarding, and possible credit contraction.

Careful statements of the proposed charges and their probable effects were prepared and sent to the Banking Code Committee, the National Recovery Administrator, and the Secretary of the Treasury with the request that the effective date for these charges be postponed until the matter could be studied more fully. As a consequence of these statements and protests from other sections of the country, the National Recovery Administrator did postpone the effective date. It was later decided that local clearing house schedules should be submitted individually for approval. A large number of these had been pending for some time before the recent deletion of Article VIII.

During the year many individual banks and clearing house associations adopted service charges on their own initiative as in the past. Apparently this process will continue. In most cases these charges are less burdensome than those first submitted to the NRA. The current tendency to impose and increase such charges, however, appears to be a reversal of the long-time trend. The past history of deposit currency has been one of gradual elimination of exchange and other charges on checks in the interest of the general welfare.

Study of the various measured service schedules and systems of activity cost analysis commonly used by banks reveals several fundamental weaknesses. In banking as in many other lines of business joint and overhead costs constitute a grave obstacle to any kind of cost determination. The attempt to arbitrarily separate such costs is likely to lead to false conclusions.

A number of popular articles giving the results of this study were prepared during the year. Detailed analysis of the cost and historical aspects of the problem were stressed. Emphasis was laid on approaching the problem from the point of view of public welfare and the banking system as a whole rather than from that of the individual bank. It may well be that accounts which appear unprofitable to a single bank are in the aggregate important to the whole banking system. Furthermore, as a matter of sound social policy it is doubtful whether checking facilities ought to be placed beyond the economic reach of large numbers of people.

National Recovery Research—Special Studies with Emergency Funds. (R. L. Mighell.) This project was set up to include all the professional and technical studies carried on with CWA and ERA funds under the direction of the Massachusetts Agricultural Experiment Station at the Massachusetts State College, during the six-months' period March 3, 1934, to August 30, 1934. An average of about 100 and a total of nearly 200 different persons were employed during this period.

The project was divided into forty-three sub-projects covering studies in nearly all departments of the college. As far as possible these studies were designed to supplement and fill in gaps in the normal research program and to accomplish results capable of immediate application to the problems of recovery. Since much of this work is reported elsewhere in this bulletin, only a few of the studies will be mentioned here. A primary objective of the project was to secure normal employment for the personnel. With the aid of the college placement service and other members of the staff, about sixty persons were assisted in finding permanent or semi-permanent positions before the project ended.

With the cooperation of the New England Crop Reporting Service, an acreage census of cranberries, asparagus, and strawberries was completed. Likewise a checkup of onions, tobacco, and potatoes in the Connecticut Valley was made. These studies fill a serious gap in crop reporting statistics and will improve the official estimates for several years to come.

Results from a study of farm production credit needs are being used by the Farm Credit Administration in Springfield in developing a sound production credit policy.

A preliminary economic study of the Worcester and Boston produce market areas was completed to the point of furnishing a quantitative description of the sources of supply and the marketing channels for local fruits and vegetables. Tentative plans for a number of new alternative regional market sites and layouts were made.

The development and construction by the psychology department of several pieces of scientific apparatus for testing the ability of automobile drivers promises to be of great practical value in the present effort to attain greater highway safety.

The plan followed, of supplementing the regular program and spreading the responsibility for the project among the several departments, led to much greater accomplishment than would otherwise have been possible.

Farm Tax Delinquency and Farm Real Estate Values. (R. L. Mighell.) This supplements the nationwide CWA Farm Tax Delinquency Study carried on by the Federal Bureau of Agricultural Economics. About 9000 tax delinquency records, 230 tax sale records, and 4000 real estate transfer records were obtained from 37 selected Massachusetts towns. The six-year period 1928-1933 was covered in most of these towns. Only preliminary local summaries were made before the records were required in Washington for tabulation and analysis in the national study.

These first summaries show that farm tax delinquency in Massachusetts, as measured on the penalty date, increased steadily during the six-year period, but very little delinquency continued to the point of a tax sale. In many cases of mortgaged property, real delinquency is doubtless concealed as mortgage holders have frequently paid the taxes rather than permit the property to be sold. Likewise abatements and exemptions have sometimes been allowed in cases of old age and relief.

Many of the farm real estate transfers consisted of transfers to public and semi-public uses such as schools, reservations, and summer resorts. The actual level of land values is difficult to determine since the true consideration was shown in only about 10 percent of the transfers.

As a matter of interest, several large areas of "lost" land were found in southeastern Massachusetts. No legal record or description exists and this land is therefore untaxed although in some cases occupied.

Enterprise Relationships and Farm Organization on Selected Dairy Farms in Massachusetts. (R. L. Mighell.) Due to civil works and emergency relief activities the work on this project was largely suspended. The study is concerned with the economics of the combination of farm enterprises and of cost factors within each enterprise. Studies of efficient labor routine in regular daily work and specific farm tasks on dairy farms will be continued. The budget method of approach with typical farm cases is being used in determining the most profitable combinations.

Labor Saving Methods and Technique on Vegetable Farms. (R. L. Mighell and R. H. Barrett.) The limited time available for this study in 1934 did not permit much new work. Continued analysis of motion pictures and records secured in 1933, however, confirmed previous conclusions as to the significant savings in time and effort possible through the application of "scientific management" methods to vegetable production. Improved methods of harvesting, bunching and packing asparagus, for example, are being adopted by growers on the basis of recommendations resulting from this study.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920, Chapter 94)

Seed Control (General Laws, 1927, Chapter 94)
Dairy Law (General Laws, 1920, Chapter 94)
Advanced Registry Testing
Miscellaneous Work

Feed Control. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski, F. A. McLaughlin, J. T. Howard.) During the fiscal year, 1,641 samples of feeding stuffs were officially collected and examined in the control laboratories. The results show that at least 94 percent of the samples collected varied less than 1 percent from stated guarantees in protein, fat and fiber content. The gross receipts from the registration of feeding stuffs in 1934 (calendar year) were $21,400, derived from 1,070 brands at $20 each.

Seed Control. (P. H. Smith, F. A. McLaughlin, Margaret E. Nagle.) From October 1, 1933, to October 1, 1934, the seed laboratory analyzed 1,627 samples of seed, of which 768 were collected by the State Commissioner of Agriculture, 482 sent in by dealers and farmers, 185 received from the Rhode Island Commissioner of Agriculture, and 192 purchased from wholesalers for special tests. Classification of these analyses is shown by the following summary.

	Massachusetts Official	Massachusetts Non-Official	Rhode Island	Totals
Purity analysis only	41	40	36	117
Purity and germination	160	32	148	340
Laboratory germination only	567	410	1	978
Field germination*		192		192
				1,627

*Samples germinated in the field are duplications of 192 samples of corn germinated in the laboratory.

Field tests to determine trueness to type were again conducted in cooperation with the Department of Vegetable Gardening which tested 192 samples of sweet corn and 187 samples of vegetable seed.

Dairy Law. (P. H. Smith, J. T. Howard, H. L. Allen.) During the year ending December 1, 1934, 6,227 pieces of Babcock glassware were tested. Condemned glassware consisted of one milk-test bottle and one pipette. One hundred and nine certificates of proficiency were awarded.

Two hundred and nineteen creameries, milk depots and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, two machines were condemned, and repairs were ordered on nineteen. Seven plants were re-inspected to approve repairs.

This act has been amended to give to the Commissioner of Agriculture concurrent power in its enforcement. Through an arrangement with his office the experiment station will continue to test glassware, issue certificates of proficiency, and make the annual inspection of machines and apparatus. The Commissioner through his deputies will conduct all check tests where methods or accuracy are in question.

Advanced Registry Testing. (P. H. Smith.) Advanced registry testing has been supervised by this department since its beginning in 1902. There are now on yearly test 321 cows located on 42 different farms. This does not include the herd tests where all animals in each herd are placed on test. Of these there are twenty-two, six of which are supervised by men sent out from this office and sixteen by cow-test association supervisors.

Miscellaneous Work. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski.) Numerous analyses have been made for residents of the State and other departments of the college.

Summary of Miscellaneous Work, 1934

Materials sent in:	
Milk and cream, butterfat only	140
Milk, solids and fat	5
Feeds, from farmers and dealers	78
Feeds, from State Institutions	53
For other departments of Experiment Station and College:	
Milk, for butterfat	244
Dry matter, forage crops	769
Complete fodder analyses	59
Dry matter and nitrogen	57

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski, Chemists; J. T. Howard, C. L. Whiting, A. G. Brigham, G. E. Taylor, Sampling Agents; Harry L. Allen, Laboratory Assistant.) Records for the year show that 118 firms have registered for sale in the State of Massachusetts 439 brands of mixed fertilizer and fertilizing materials and 46 brands of agricultural lime and gypsum. Results of analysis show that about 72 percent of the fertilizer brands and 84 percent of the lime brands showed no deficiencies. The gross receipts from the registration of the fertilizer and lime products and from fertilizer tonnage fees for the year 1934 were $13,029.

For ten weeks beginning April 1, four experienced men employed to draw samples for inspection purposes sampled 19,086 sacks or containers, representing 7,751 tons of material; 920 agents were visited. The following summary shows the character of these substances, as well as statistics with reference to their inspection.

	Brands Registered	Brands Collected	Samples Drawn	Number of Analyses	Number of Determinations*
Mixed fertilizers	269	273	1,027	464	6,227
Ground bone, tankage and fish	47	47	157	72	535
Nitrogen products, mineral and organic	44	44	179	92	186
Phosphoric acid products	20	20	94	31	124
Potash products	12	12	59	25	71
Dried pulverized natural manures	25	26	102	40	255
Nitrate of potash	5	5	12	8	36
Peat products	9	9	20	11	40
Wood and cotton hull ashes	3	3	8	8	59
Miscellaneous	7	7	17	11	70
Lime products	46	45	98	48	404
Totals	487	491	1,773	810	8,007

*Not counting check tests or repeats, which amounted to 962.

During the period July 1, 1933, to July 1, 1934, the tonnage of fertilizer and plant food, and lime products as soil amendments, sold in Massachusetts was as follows:

	Fertilizer (Tons)	Plant Food Elements (Tons)		
		Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	40,160	2,028	3,438	2,745
Unmixed fertilizer chemicals and materials	15,870	1,144	1,344	484
Pulverized natural manures	1,614	33	24	44
Totals	57,644	3,205	4,806	3,273
Lime products (as soil amendments)	40,433			

Full details of the fertilizer and lime inspection will be found in Control Bulletins 74 and 76.

Miscellaneous Analytical and Diagnostic Work. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski.) Chemical studies of a cooperative nature have been carried on, as has been the custom in the past, with the several departments of the institution, Field Station and County Agents. The character and extent of this work is shown in the following summary:

Calcium and magnesium superphosphates	2
Chicken mash	3
Clay pots (plant food absorption experiment)	4
Copper sulfate	5
Greenhouse soils (complete analysis	3
Hay, cured	55
Leg bones of chickens	10
Manures	2
Milk ash	8
Plants from greenhouse	4
Sphagnum moss	3

Other chemical work of the department has included service to community organizations, State institutions, and individuals interested in agriculture. This group includes the following materials:

Animal tissue for arsenic	1
Carnation soils(complete analysis)	3
Complete fertilizers	3
Compost	1
Fertilizer by-products	7
Fertilizer chemicals	9
Grain ration for chickens	1
Irrigation waters	2
Lime products	4
Manures	2
Midrib of tobacco leaves	2
Peat products	6
Sewage sludge	1
Spent mushroom soil	1
Soils	11
Tobacco leaves cured	2
Tobacco leaves damaged	2
Water for poultry plant	2

Research work on methods of potash determination in fertilizers has been done in cooperation with the Association of Official Agricultural Chemists of North America; other service of an advisory and executive nature has also been rendered to this organization during the year.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) Breeding and selection work is being continued with strains now in the F_5 generation. Some ten to fifteen strains of the F_4 generation were grown in the field during the summer, for resistance under field conditions; and, while many of the lines have continued to segregate for resistance, two strains have been selected which are uniformly resistant to rust. These strains are yellow and white flowered types which have bred true for color for three generations. During the past season both strains were tested under greenhouse and field conditions at the University of Michigan by Dr. E. B. Mains, where they were found to be uniformly resistant to rust.

Further breeding and selection work will be carried on to develop 100 percent rust resistant strains in other flower colors.

Propagation Studies on Geraniums. (Harold E. White, Waltham.) Short cuttings, four to five nodes in length, rooted 10 to 20 percent better than long cuttings of six to eight nodes. On six- to eight-node cuttings the rooting response was in favor of the cut being made through or below the node, whereas in the case of four- to five-node cuttings the rooting response was good irrespective of the location of the cut.

Sand and peat as a rooting medium was 10 to 15 percent better than sand only. A mixture of three-fourths sand and one-fourth German peat was found to be the best rooting medium. Soaking the cuttings for one hour in potassium permanganate solution, one ounce to five gallons of water, prior to placing the cuttings in the medium, gave more favorable results than treating the medium with potassium permanganate solution, one ounce to two gallons of water, applied at the rate of one pint per square foot.

Starch was found to be much more abundant near the nodes on soft-wood cuttings than between the nodes. Less starch was found to have accumulated at the nodes in cuttings of older wood.

Study of the Effect of Plant Nutrients, Soil Reaction, and Light on Gardenias. (Harold E. White, Waltham.) A definite growth response in gardenias was observed when nitrogen and phosphorus were used in increasing ratios. The response was more pronounced in sand than soil, particularly with phosphorus, due to the probable high degree of fixation of the soil over sand. Increasing amounts of potash had no visible effect on growth either in soil or in sand, which would indicate a low potash requirement for gardenias. Definite growth response to nitrogen and phosphorus in the soil was manifest only after the higher planes were reached, chiefly with phosphorus.

Low nitrogen was indicated by uniform chlorosis of the foliage and dwarfing of the plants. Interveinal chlorosis was severe on plants fed with calcium nitrate as a source of nitrogen and plants showing interveinal chlorosis became green again after being sprayed with a solution of iron sulfate. Plants that received nitrogen from an ammonia source showed less interveinal chlorosis.

On the basis of soil pH studies it would seem that soil reaction alone is not a safe basis on which to judge the possibility of interveinal chlorosis occurring on gardenia plants, since experimentally chlorosis appeared on plants when the pH readings with a potentiometer ranged from pH 5.0 to 6.1.

From the data obtained it appears that gardenias require more iron for normal growth than the average ornamental crop or, at least, they are very sensitive to any condition that may tend to reduce the amount of available iron in the soil.

Propagation Studies on Gardenias. (Harold E. White, Waltham.) Work on this project has been delayed due to the fact that repairs on the greenhouse were not completed in time to permit propagation work to start on the date specified.

Study of the Effect of Plant Nutrients on Carnations Under Glass. (Harold E. White, Waltham.) This investigation has been completed and the results will soon be brought together for publication.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Technological and Nutritional Investigations of New England Apples. (C. R. Fellers, J. A. Clague and P. D. Isham.) Studies were continued on ten varieties of apples for cider making qualities. Blends made from combinations of the varieties were compared with the straight ciders.

A comparison of methods of clarification and filtration showed that the enzymic clarification with Pectinol was the simplest and most effective for general use. The gelatin-tannin treatment produced a clear cider, but removed much of the original color. The filter developed at the Michigan Agricultural Experiment Station was tried out and found to be an inexpensive, simple and satisfactory means of filtering the cider.

Preservation of cider may be successfully accomplished by pasteurization, by filtration through asbestos and germ-proof filter or by chemical preservatives such as sodium benzoate. Pasteurization, if carefully controlled, is probably the best method for the small manufacturer to use for filtered cider. Some preliminary work was done with the electro-silver ionic method of preservation with not very encouraging results. The manufacture and sale of cider affords a very effective outlet for the cull apples of Massachusetts. Now that a simple method of clarification has been developed, clarified cider should create a demand for this product from those people who objected to the "muddy" appearance of the unclarified juice.

Twenty-one varieties of Massachusetts-grown apples have been assayed for vitamin C content during the past two years. These results are presented in a paper in the *Proceedings of the American Society for Horticultural Science*, Volume 31, 1934, and briefly in the *Annual Report of the Massachusetts Fruits Growers' Association* for 1934. There is no apparent correlation between vitamin C content of an apple variety and the chromosome number of that variety. Seasonal or other variation except storage caused little change in vitamin C content in the same variety. The varieties richest in vitamin C are Baldwin, Northern Spy, Ben Davis and Winesap.

When apples were made into apple pie less than 20 percent of the vitamin C was retained. On the other hand, baked apples retained from 80 to 90 percent of their original vitamin C. Sulfured evaporated apples lost approximately 65 percent of their vitamin C content.

Cranberry Products. (C. R. Fellers, J. A. Clague and P. D. Isham.) A paper on the relation of benzoic acid content and other constituents of cranberries to keeping quality was published in *Plant Physiology* 9:631-636 (1934). The mean benzoic acid content of 24 varieties of cranberries was 0.065 percent. The varieties with the best keeping qualities did not always have a high benzoic acid content; hence other factors are largely responsible for the differences in keeping quality. Unlike benzoic acid, quinic acid exerted no appreciable preservative action against molds, yeasts or bacteria. Neither pectin nor soluble solids of cranberries showed any correlation with keeping quality. In general, the most acid varieties were the best keepers.

The malic acid content of both immature and mature Howes cranberries was 0.26 percent. The citric acid content of immature Howes averaged 1.31 percent and of mature Howes 1.07 percent. Over 0.5 percent quinic acid was positively isolated from cranberries and possessed the same chemical and physical properties as quinic acid obtained from cinchona bark. The isolation was accomplished through the formation of the basic copper salt of quinic acid. This proof of the presence of quinic acid in cranberries aids greatly in explaining the effects observed in the urine and blood after the ingestion of large quantities of cranberries.

Several popular articles were published dealing with the nutritive value of cranberries.

Utilization of Cull Onions. (C. R. Fellers.) This project has remained inactive except for the occasional examination of experimental packs of canned, dried (powder), and pickled onions prepared during the past two years. A start has been made on some studies of the nutritive value of Connecticut Valley onions.

Tomato Juices. (C. R. Fellers, J. A. Clague, and M. J. Mack.) For the second season, homogenization of tomato juices had only a very slight injurious effect on their vitamin C content, and greatly enhanced their attractiveness because it prevented separation of solids. Six commercial brands of canned tomato juice varied in vitamin C potency from 2 to 8.5 grams as the daily protective dose for guinea pigs. Home-prepared juices compared favorably with commercially manufactured ones in vitamin C content.

Effect of Freezing, Cooking, Canning, and Fertilizer Treatment on the Vitamin A and C Content of Green Asparagus. (C. R. Fellers, R. E. Young, and J. A. Clague.) The research under this project has been completed and a paper is now in press. Fresh and frozen asparagus are excellent sources of vitamins A and C. Fertilization with nitrogen and potash had but little influence on the vitamin A or C content. Both cooking and canning green asparagus resulted in a 60 to 80 percent loss of vitamin C. No loss in vitamin A was noted.

Red Squill Research. (R. E. Buck and E. M. Mills.) This study is financed by the U. S. Biological Survey and has for its purpose the perfecting of red squill rat baits. Methyl and ethyl alcohol extracts of red squill have proved to be very toxic in laboratory and field tests on rats. Unlike the powder, the squill extract when mixed with meat, fish, or cereal baits is palatable to rats. If a sub-lethal portion is eaten by rats, they will continue to eat baits containing squill extracts. This is not true in the case of squill powder. Work has been started on the isolation of the toxic principle of red squill.

Nutritive and Technological Studies on Fishery Products. (C. R. Fellers, J. A. Clague and F. P. Griffiths.) The Atlantic whiting was successfully canned by brining, pre-cooking, boning, exhausting, and sterilizing at a temperature of 240°F. for 60 minutes for one-half pound cans. The whiting also made satisfactory canned fish cakes and chowder.

The fish meal studies have been continued in a limited way. There is very little difference in the nutritive value of extracted and non-extracted fish meals as supplementary sources of protein for chicks or laying hens. Vacuum-dried meals were significantly superior to flame-dried ones for both rats and chicks.

Work is now under way to determine the biological value of the proteins of the mackerel and crab by rat feeding experiments. Mackerel oil was found to be a poor source of vitamins A and D.

The preparation and use of waste fish products as dog foods has been given some attention.

Home Canning Research. (W. A. Maclinn, Pearl Haddock, C. R. Fellers and W. W. Chenoweth.) A simple new method for the determination of partial pressures in sealed glass containers was perfected. The method of processing fully sealed glass jars of canned food has been successful for all fruits and for most vegetables when processed in the water bath. However, at the present time the method cannot be recommended for canning meats, fish, or vegetables processed in the pressure cooker or oven. Many new data on pressure, headspace, vacuum, venting, heat penetration, and cooling of glass containers during and after heat treatment have been collected. When fully collated these data will help to explain what actually occurs in the jar of food during processing. Oven canning studies show that while this method cannot be recommended for general home use, the type of oven and container are important factors. Small oven loads are sterilized much more rapidly than large ones. The optimum temperature range for the oven is 250° to 300°F. The presence of a pan or tray of water in the oven during processing definitely retards heat transfer in the jars of food.

Maple Products. (C. R. Fellers.) A paper on the content of vitamins A and C in maple products is in press. The results were all negative. Maple syrup was successfully canned in sealed tin cans and the experimental packs have maintained their original quality for over a year. This method of preserving maple syrup should have wide use.

Microbiology of Dried Foods. (J. A. Clague in cooperation with the Department of Bacteriology.) Preliminary studies show that yeasts are destroyed by the usual methods of dehydrating prunes and grapes. Using *Esch. coli* as an index of intestinal contamination, dehydration effectively destroyed this type of organism. The principal contamination of bulk dried foods is at the surface of the mass.

Blueberry Investigations. (C. R. Fellers and Oreana Merriam.) Chemical and vitamin C studies were conducted on six cultivated and one wild variety of *Vaccinium corymbosum* and on wild *V. pennsylvanicum* from Massachusetts and from Maine. Blueberries are fair to good sources of vitamin C. Little difference in potency was noted among the cultivated varieties, though marked variations in chemical composition were found. Commercial and home methods of canning conserved to a considerable degree the vitamin C of blueberries. Freezing had practically no effect on vitamin C in blueberries.

DEPARTMENT OF OLERICULTURE

Ralph A. Van Meter in Charge

Packet Seed Studies. (G. B. Snyder.) One hundred and seventy-two lots of packet seeds representing beans, beets, cabbage, carrots, cauliflower, celery, cucumbers, lettuce, onions, parsnips, radish, turnips, spinach, and squash were obtained by State inspectors and planted in the trial plots. Field germination of the seed was recorded and the results obtained listed half of the lots as having a germination of 70 percent or better and half as having a germination below 70 percent. Sixteen percent of the lots germinated less than 30 percent.

In general the varieties ran fairly true to the name printed on the seed packet. The carrots were very much off type, and in lettuce and spinach there was mixture in some of the varieties.

This project was carried in cooperation with the Seed Laboratory.

Studies in Sweet Corn, Including Seed Germination, Seed-Borne Diseases, Variety Characters, and Factors of Quality. (A. P. Tuttle and G. B. Snyder.) In cooperation with Professor F. A. McLaughlin, Seed Analyst, and Dr. O. C. Boyd, Plant Pathologist, the Department of Vegetable Gardening studied the field performance of some 245 lots of sweet corn. While there was some variation in plant characters and in the performance of strains within varieties, practically all the strains fell within their respective variety range and were true to name.

Some 70 so-called hybrid varieties were included in the trials and compared with the standard varieties grown. In general the hybrids were slightly later in maturity, had larger plants and ears, produced a slightly heavier yield, and the kernels were sweet and oi good quality. Some of these hybrids are of outstanding commercial value.

Studies of kernel toughness of such varieties as Sunshine, Golden Gem, and Spanish Gold indicated that, while kernel toughness tended to increase with age of the kernel, other conditions not within the scope of these investigations were perhaps more important than age in determining toughness. Harvesting of the ear did not materially affect the rate of increase in toughness of the kernel.

Systematic Studies of Turnips and Rutabagas. (G. B. Snyder.) This project was carried in cooperation with the Federal Division of Fruit and Vegetable Crops and Diseases. Thirty lots comprising fourteen varieties of rutabagas and eighty-five lots comprising seventeen varieties of turnips were gown in the trial plots. Detailed records were taken of the plants during the growing season and of the roots at the time of their prime market stage of maturity. This is at least a two-year project.

Systematic Studies of Onions. (G. B. Snyder.) This project was carried cooperatively with the Federal Division of Fruit and Vegetable Crops and Diseases. Thirty-nine lots comprising twenty-three of the more important commercial varieties of onions were grown in the trial plots. Detailed records were taken of the plants during the growing season and of the matured bulbs. This material will be used as a part of the Federal bulletin describing the types of American varieties of onions.

Asparagus Investigations. (Robert E. Young, Waltham.)

Fertilizers. It has been necessary to curtail part of the asparagus fertilizer work because of lack of funds. The plots located at Concord were relinquished early in the spring before the cutting season; the plots located at North Eastham on Cape Cod were given up at the end of the cutting season. The plots at Waltham will probably be continued until more conclusive results have been obtained.

The plots at North Eastham have been cut for three full cutting periods. The soil on which these plots are located is classified as Merrimac coarse sand. The organic matter content is very low. Although harvest records have been obtained from these plots for only three full years, fertilizer has been applied for the past five years, the roots having been set in 1929. While the results under these conditions are not conclusive, they do give some very definite trends, as follows:

1. Fertilizer containing 8 percent nitrogen applied at the rate of 1 ton per acre gave the best results in the nitrogen series. Nitrate of soda was the best nitrogen carrier.
2. A fertilizer mixture containing 12 percent phosphoric acid, where the phosphorus was derived from superphosphate, gave the best results in the phosphorus series.
3. A fertilizer containing 6 percent potash gave an average increase of 31.6 percent as compared to a fertilizer containing no potash. The results indicate that muriate of potash is the best form.
4. The substitution of salt (NaCl) for muriate of potash resulted in reduced yields. Salt added to a complete fertilizer did not increase yields.
5. The indications are that the nitrogen fertilizer should not all be applied at once, but that one-half should be applied at the end of the cutting season and the remainder one month later. Apparently, some of the nitrogen is lost from this very sandy soil at Eastham when it is all applied at once.
6. One of the most outstanding results of the experiment was the increase in yield obtained by the use of organic matter in the form of seaweed plus 350 pounds of superphosphate per acre.
7. Asparagus was greatly benefited by an application of lime to the acid soil. The limed soil gave an increase of 21.8 percent as compared with the unlimed.

The Waltham plots continued to increase in yield in 1934, although the increase was not as great as that obtained last year. The yield records show about the same results as last year, and about the same as those obtained at the North Eastham plots. One of the differences is that increased yields may be obtained by 12 and 18 percent potash in the fertilizer mixture, provided the nitrogen in the fertilizer is raised from 8 to 12 percent. Better results were obtained when the fertilizer was applied May 1. Although the soil at Waltham is well supplied with organic matter, the plot which receives manure and superphosphate continues to give high yields. A very good kill of weeds was again obtained by the use of Cyanamid in both powdered and granular form.

Depth of Planting and Height of Cutting. The results of this experiment have not changed greatly from those of last year. The plots where roots were planted shallow (2 and 4 inches deep) continue to give the greatest yield, the difference in yield being due mainly to the loss of plants where the roots were planted deeper than 4 inches.

The plots where the asparagus is cut with 12 inches of green seem to be losing some of the advantage in yield that they had at the beginning of the experiment. Cutting the asparagus with only 4 inches of green did not result in an increased yield as compared to the plots cut with 8 inches of green. The results of this experiment to date indicate that cutting asparagus with a full 8 inches of green does not reduce the total yield and does result in an increased market value of the asparagus.

Varietal Improvement. During the past two years, individual records of 278 selected asparagus plants have been kept. These plants were selected in an attempt to obtain a high-yielding strain. Of the 278 plants, 131 are females and 147 males. In 1934, the females produced 9.37 stalks per plant and the males 13.82. The average yield per plant was 12.22 ounces for the females and 13.48 ounces for the males. Of the 10 highest yielding plants, 5 were female and 5 male. Six plants that ranked in the high 10 in yield in 1934 were in the high 10 in 1933. From these indications, it should be possible to obtain consistently high-yielding parents which should produce high-yielding progeny.

Seed Improvement. (Robert E. Young, Waltham.) Progress has been made in the improvement of the French Horticultural bean and samples of the seed will be distributed to bean growers throughout the State. The stock seed crop proved to be a highly colored bean, a large proportion of which was ready for harvest at the same time. In comparison with one of the best commercial strains, the Field Station strain produced larger beans and a greater total yield by 10 percent. The bean crop this past season was remarkably free from the bacterial blight disease that was so prevalent a year ago.

Sixty-six samples of Waltham Beauty pepper seed were distributed to growers last year. In response to a questionnaire sent these growers, 54 returned cards giving information regarding the crop. Analyses of these results show that 43 growers considered the yield of the pepper satisfactory, and 38 considered the pepper better than any commercial variety they had grown. Samples of seed will be available in 1935. Arrangements will be made for a commercial crop of seed since most of the growers trying it felt that it was a definite and desirable addition to the pepper variety list. The pepper was exhibited at the Fall Vegetable Show of the Massachusetts Horticultural Society and was given an Award of Merit.

Selfing strains of Blue Hubbard Squash for the past few years has resulted in a very uniform strain this past season. During this selfing it seemed impossible to maintain the roughness of the skin that is so desirable in squash for Massachusetts markets. The color, hardness of rind, thickness and color of flesh, and yield, were satisfactory. The shape was approximately desirable. Crossing will be necessary to produce the exact type desired.

Considerable improvement was noticed in the stock seed of the Field Station strain of Hutchinson carrot. The particular character on which improvement is being attempted is the interior color. Crosses with darker varieties were made in the greenhouse in the spring of 1934. The seed was planted outside for a fall crop. The majority of these F_1 roots showed a much darker color than the regular strain. Excellent individual roots from regular stock seed were selfed during the past season in an attempt to further improve the uniformity of the roots. There continues to be a strong demand for seed of the Field Station strain of Hutchinson carrot from the local market gardeners association.

At the request of some of the local market gardeners, selfed selections of Bel-May lettuce have been made and grown to improve the appearance of the lettuce. Since the lettuce is packed for market with the head down, it is necessary for the bottom leaves to completely overlap. If the leaves do not overlap where attached to the stem, the head will not have the appearance of solidity regardless of how solid it may really be. Selfed lines now being grown show considerable improvement in regard to this character, as compared with the regular strain of this lettuce.

The Field Station strain of Comet tomato for greenhouse culture has gained in popularity in the past year. Both selection and crosses have been made to improve the size of this tomato. Samples of seed are available at the Field Station. The seed is being merchandized by the local market gardeners association.

Some progress is being made in improving the color of the Wyman Crosby beet. In trials at the Field Station it compared very favorably with commercial strains as regards uniformity, shape, size, and top growth. Work will be continued for improvement in color before the seed is offered for trial.

Cucumber seed of the Belleville variety has been increased from seed produced by one of our leading cucumber growers. Samples are available.

Pascal Celery Storage. (Robert E. Young, Waltham.) Preliminary work was conducted last year to determine the effect of temperature on the keeping of Pascal or Boston Market celery. This experiment was not fully under way until late in the season due to the fact that the storage plant was not completed until late in December. As was expected, the celery held at low temperature kept longer than celery maintained at a temperature of 40° to 45°F. Celery was taken from storage in marketable condition two weeks after most of the local produce had disappeared from the Boston Market.

DEPARTMENT OF POMOLOGY

F. C. Sears in Charge

The outstanding characteristic of the past year was the unusually severe winter and the resulting damage to orchards and fruit crops. There were two periods of severe cold, one the last week in December and the other in the first half of February. Full records of the winter temperatures are shown in the monthly meteorological bulletins of this station.

The peach crop was a complete failure and many trees over ten years old were killed or very badly injured; trees under five years old suffered somewhat but not severely. Pear trees showed severe browning of the pith and xylem especially in the spurs, and some trees were killed or badly injured. Considering this severe browning, pear trees generally recovered better than was expected and the total permanent injury is believed to be small. The sweet cherry orchard planted in 1927 showed injury to some varieties such as Napoleon and Lambert, while Windsor, Seneca, Schmidt, Stark Gold, and Gov. Wood suffered little injury and bore fair to good crops. Sour cherries showed little injury. The injury to cherry trees was confined to crotches, trunk, larger limbs, and fruit buds.

Because of the size of the industry apple orchards suffered the greatest damage. Many trees of the more tender varieties were killed or badly injured. Injury was worst in Franklin and Plymouth and least in Hampden counties. Four different types of injury could be distinguished: (1) killing of the pitch and xylem, weakening or killing certain branches or the whole tree, (2) loosening and splitting of the bark on the trunk, (3) injury to the spurs and weakening or death of the flowers, (4) killing of patches of bark generally on the larger branches but without loosening from the wood.

The first type was common on the Baldwin and caused the greatest damage. It was most severe on older trees weakened from any cause, frequently the temporary weakness from a heavy crop in 1933. Leaf area was severely reduced, both in size and number of leaves. Usually low branches suffered more than those in the upper part of the tree but this was not always the case. Some trees or branches thus injured recovered more or less during the summer, but others died.

The second type, bark loosening, was most common on McIntosh but occurred also on Wealthy, Wagener, Gravenstein, Red Astrachan, and Baldwin. Some trees were completely, but most of them only partially, girdled. This type of injury appeared only on trees ten to twenty years old and seemed most common in orchards in cold locations exposed to the sweep of winds. It was almost always on the northwest side of the tree. There seemed to be no correlation with tree vigor and there was but little injury to the foliage. In many orchards the loose bark was tacked down and the wound waxed. Where a careful job was done, using nails long enough to hold the bark firmly, recovery seems to have been favored. Possibly the full amount of damage to the injured trees has not yet appeared.

The third type of injury resembled the first but was confined to the spurs. It was generally associated with the first type and confined almost entirely to Gravenstein and Baldwin. Sometimes the flower buds failed to start, or they might get as far as the pink stage and then perish. The damage from this type is mostly from the reduction or loss of the 1934 crop, though some spurs were entirely killed.

The fourth type was like the second but found generally on the larger branches and in the crotches, not the trunk, and the bark remained tight to the wood. The injured area soon became clearly demarked and sunken. It was confined almost entirely to the Baldwin. The permanent damage will be least of any of the four types except when rot is allowed to enter. Where there was crotch injury, a serious weakening of the tree may be expected.

It was estimated that of the Baldwin trees in the State 5 percent were killed, 5 percent too severely injured to be worth retaining, 20 percent severely injured but most of which will recover, while 50 percent were slightly injured but will suffer little permanent damage. This leaves 20 percent of the trees free from visible injury. It is difficult to estimate the damage from bark injury to the McIntosh. Only future years will disclose, but at present it is not considered to be disastrous. There was some permanent damage to Gravenstein in addition to reduction of the 1934 crop. Minor varieties suffered more or less according to their hardiness or lack of it. The principal unusual injury was the bark loosening on the McIntosh.

All varieties of grapes except Concord and Worden suffered more or less winter injury. Vinifera varieties were badly killed even though they were given the usual winter protection.

The apple crop in the station orchards was 17 percent below that of 1933. Injury to the trees was not severe and only a few Baldwins and some trees top grafted two years ago were killed. An old peach orchard already weakened from arsenic injury occurring several years ago was mostly killed. The trees also seemed to be suffering from the new disease reported from Connecticut.

The Interrelation of Stock and Scion in Apples. (J. K. Shaw.) Interest in this orchard centered around the apparent cause of poor growth, a lack of potash. The entire orchard except four rows received, in addition to sulfate of ammonia, about 3 pounds of muriate of potash per tree. Little if any improvement in growth was noted though the two rows that had been fertilized with potash in previous years continued to present a better appearance.

Preliminary work with the Thornton test for potash in plant tissues showed more or less abundant potash in the leaf petioles of the trees that had had three annual applications of potash, but the trees having potash in 1934 only showed little, if any, more than those having no potash. There seemed to be little potash in these last trees. There appeared to be much difference between individual trees and but little between varieties, except that Wagener seemed very low in potash. This variety has performed very poorly in this orchard. No relation between potash content of the trees and the root stock was shown but this deserves further study.

Some work has been done in tabulating and studying the data accumulated during the 18 years of the life of this orchard and a publication will be made as soon as the study is completed.

Excavations were made around the stumps of trees cut out to study the root distribution. This will be reported later. It was concluded that the stock influenced the type while the scion controlled the size of the root system.

Studies of the Malling types of clonal roots were continued. Surplus wood of several types was grafted on short pieces of seedling roots in April and at once planted. Results were as follows:

Malling Type Number	Number of grafts planted	Percentage Living	Percentage Rooted
1	221	58	84
4	135	53	80
6	16	0	—
8	68	0	—
9	105	0	—
10	97	60	81
12	110	64	60
13	70	61	52
15	50	54	37
16	149	60	77

This method of nurse root grafting may be used for propagating these stocks. If allowed time to callus before planting, better results might be obtained. The nurse roots were cut off and the rooted scions replanted.

The first crop from a stool bed planted in 1933 was harvested. Rooted layers per 100 stool plants were as follows:

Malling Type Number	With Strong roots	With Weak roots	Total
1	54	84	138
2	48	128	176
3	207	243	450
4	150	211	361
5	57	205	262
6	64	152	216
8	150	132	282
9	95	79	174
10	18	130	148
12	14	111	125
13	60	200	260
15	25	138	163
16	53	225	278

There is considerable variation in the yield of the several stocks. Yields should be larger as the plants become older.

An orchard of 344 trees, mostly Baldwin, McIntosh, Starking, Red Spy, and Macoun budded on several Malling stocks, was set on the fruit farm of R. S.

Schoonmaker in Amherst for a study of the behavior of these varieties on these stocks. More than 2,000 Malling stocks were budded to several commercial varieties for further studies of this relationship.

The young orchard set in 1928, known as Block D, consisting of McIntosh and Wealthy on Malling stock, bore its first real crop. Following are yields per tree and trunk diameter:

Stock Type	Trunk Diameter (mm.) November 1933		Average Total Shoot Growth (in.) 4 yrs.		Yield 1933-34 (lbs.)	
	Wealthy	McIntosh	Wealthy	McIntosh	Wealthy	McIntosh
1	29	80	—	60	10	69
2	37	24	—	27	24	0
3	27	23	—	—	10	0
4	77	96	28	62	149	135
5	60	66	24	64	39	52
6	46	67	56	66	34	19
8	23	18	27	30	0	0
9	21	27	—	49	6	4
10	65	84	64	73	40	64
12	83	98	66	80	77	37
13	69	75	63	69	46	55
15	68	77	62	68	32	18
16	81	94	62	78	76	94
Own roots	71	93	67	72	49	86
Seedling roots	71	88	61	72	62	71

With these two varieties the dwarfing stocks, Types 1 to 9 inclusive, do not seem to have hastened production, except in the case of Type 4. Trees on this stock are large and productive but the root anchorage is somewhat weak. McIntosh does well on Type 1 while Wealthy does poorly. Types 12 and 16 are promising as stocks for standard trees. Types 2 to 9 inclusive are represented by fewer trees than are the others and the averages are less dependable.

Some studies of root distribution were made by digging semi-circular trenches partially around the trees. The trees are twenty feet apart, and the roots almost meet across this space but seem to have gone down only about two to three feet.

Tree Characters of Fruit Varieties. (J. K. Shaw and A. P. French.) Photographic records of bloom clusters on about one hundred varieties of apples were made. Flowers and flower clusters are characteristic of the variety and are of value in identifying varieties for the few days that they are available. Some time was given to the study of new varieties in connection with nursery variety inspection and the certification work of the Massachusetts Fruit Growers' Association, which was continued on the smaller scale of recent years. Occasional mixtures still appear but are very much fewer than formerly. Several hundred thousand nursery apple trees in eight different nurseries in New England and New York were examined for trueness to name. Trees of several seedlings of Rome Beauty grown from buds received from the Ohio Station, including Gallia Beauty and Rome, were available for study. Only one of these was found to differ from the others enough for possible identification in the nursery row of yearling trees. This is the first case we have met of seedling varieties that could not be identified.

Further efforts were made to establish a cherry nursery for the study of varieties. It has proved very difficult to get a sufficiently good stand of buds for study.

Some progress has been made and another effort to grow a cherry variety nursery is planned for next year.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) During the severe winter of 1933-34 all peach buds in the college orchard and a number of the older trees were killed so that no crossing could be done in the spring of 1934. Seedlings raised from pits obtained from crosses made in 1933 were set in the nursery to the number of 1158. Because of limitation of space only 1122 of the 2415 seedlings ready for planting in the orchard in the spring of 1934 were set. Although all of these seedlings had been injured more or less severely during the winter of 1933-34, only fourteen died. The rest recovered and made a very good growth.

Effect of Pruning Bearing Trees. (J. K. Shaw and O. C. Roberts.) Work on this project is drawing to a close and the results are nearly ready for publication. The old orchard used in this work has been partially removed to make room for building purposes and the remainder is of little value for the experiment and will probably be soon cut down. Some work in other orchards may be continued for a time.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) This experiment has now continued for fourteen years though with some changes in soil treatment. The yields of the several plots over this period present a rather interesting picture. Computed by two-year periods in average pounds per tree they are as follows:

BALDWIN

Plot	Treatment	1921–22	1923–24	1925–26	1927–28	1929–30	1931–32	1933–34
	CULTIVATED:							
3	No fertilizer....	39	76	8	126	484	179	450
5	N 1927.........	179	66	54	600	923	692	466
7	Complete 1930..	82	382	674	345	725	359	928
1	Complete 1930..	11	170	434	841	765	272	1485
	SOD:							
2	N 1921.........	380	510	668	694	950	345	974
4	N 1921.........	331	553	662	292	887	183	932
6	K 1927.........	354	483	567	471	737	145	862
				McINTOSH				
	CULTIVATED:							
3	No fertilizer....	427	242	117	283	415	545	545
5	N 1927.........	473	27	279	462	568	938	717
7	Complete 1930..	263	413	547	532	648	537	1266
1	Complete 1930..	34	379	383	506	679	724	1171
	SOD							
2	N 1921.........	477	634	242	393	796	630	714
4	N 1921.........	461	575	327	314	656	473	533
6	K 1927.........	559	734	483	680	1003	1064	1019

The odd-numbered plots have always been cultivated (except parts of plots 1 and 7 before 1921), and the even-numbered plots were cultivated before but have been in sod since 1921.

Plot 3 has had no fertilizer since 1921 and little, if any, before. Yields are very low.

Plot 5 was unfertilized until 1927 when annual applications of 300 pounds per acre of nitrate of soda were begun. The trees quickly responded with increased crops but this has not been maintained, at least with Baldwin.

Parts of Plots 1 and 7 were in sod from about 1914 to 1921 when the whole was put under cultivation. No fertilizer was applied until 1930 but since that time a complete fertilizer has been applied annually. These two plots produced rather better than the other cultivated plots in the earlier years of the test, then showed signs of a decline. The crop of both varieties for 1933-34 shows remarkable gains. If continued for a few years more it will be an argument for complete fertilizer.

Plot 2 in sod has had nitrate of soda 300 pounds per acre and a supplemental application of about 200 pounds in July. Plot 4 has had the same treatment but without the summer application. The additional nitrogen seems to have increased yields. Plot 6 had the same treatment as Plot 4 until 1927 when sulfate of potash 150 pounds per acre annually was added. McIntosh seems to have responded after a year or two with increased yields, while Baldwin has not. The appearance of the trees on Plot 6 is better than that of those on Plot 4 and the potash content of the leaf petiole is higher.

Comparison of Clover Sod and Grass in a Sod Mulch Orchard. (J. K. Shaw.) This project is closed. Results have been meager, but it is concluded that white clover cannot be easily maintained in orchards with phosphorus–potash–lime fertilization under our conditions. There has been some evidence that the white clover when present does supply some nitrogen to the trees but not an adequate amount. The conditions favoring the clover seem also to favor blue grass and it tends to crowd the clover out. However, it is felt that the trees grew and produced better than they would have done without fertilizer.

Tests of Different Amounts of Nitrate of Soda. (J. K. Shaw.) The practice of fertilizing in the off years only has been continued. Yields in the on year have not been maintained but in the off year, when the fertilizer has been applied, they have increased. In other words there is evident some tendency toward more regular bearing. The net result, however, is a lower total yield.

Comparison of Cultivation and Heavy Mulching for Apples. (J. K. Shaw.) Fertilization of the cultivated plots with nitrate of soda was continued and additional mulch applied to the mulched plots as it was available. Mulching has been very heavy, enough to suppress nearly all the grass beneath the trees. The lower layer of the mulch, which has accumulated for twelve years, is well decayed and filled with a mat of fine rootlets. No injury from the severe winter was noticed. The yields by two-year periods in pounds per tree since 1926 are as follows:

McINTOSH	1927–28	1929–30	1931–32	1933–34
Mulched	1452	2550	2272	2154
Cultivated	785	1220	1437	1461
Difference	667	1330	835	693
WEALTHY				
Mulched	447	752	836	896
Cultivated	323	474	676	597
Difference	124	278	160	299

The nitrate applied to the cultivated plots beginning in 1930 has apparently increased production of McIntosh, but Wealthy trees have increased in yield no more than those mulched. Perhaps the Wealthy trees are deriving some nitrogen from the seepage waters from the mulched plot located adjacent on higher ground. The filler trees on Doucin stock in these plots were cut out in 1932 and this may have been to the advantage of the trees on seedling stocks remaining. The stocks under these Doucin trees prove to be Malling Type 5 and not 6 as reported last year.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw.) Fertilizer applications were continued on these plots as for the past forty-five years. A subsoil plow was run along the borders of each plot to cut any roots seeking to trespass on an adjoining plot. This leaves a space of three feet between the plots across which it is doubtful if the roots will pass in one season. Leaf burn was, as in past years, severe on some plots, especially the unlimed potash plots. Tree growth is closely correlated with the amount of leaf burn.

Some work was done with the Thornton test for potash in the trees. This test indicated that the potash in the leaf petioles was high on all the plots receiving potash fertilizers with the exception of the phosphorus-potash plots; it was low to medium on the unfertilized plots; on the unlimed part of the phosphorus and nitrogen–phosphorus plots it was rather high, while on the limed part it was very low; on the plots receiving nitrogen only, potash was very low.

Role of Potash and Lime in Fruit Tree Nutrition. (J. K. Shaw.) Work on this project was resumed after one year. Peach seedlings homozygous for vigor factors were grown in pots in soil from the unfertilized limed plots of the preceding project. They were variously treated with sulfur and different nitrogen-carrying fertilizers, including peat and manure. Not enough sulfur was used to acidify the soil so as to seriously interfere with growth. Nevertheless some interesting results were secured.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw.) The McIntosh filler trees were removed in the spring that they might not interfere with the Wealthy trees, the entire orchard being now of that vareity. The orchard has been in sod and the appearance of the trees rather poor. The sod between the trees was cut with a heavy disc harrow in the spring, improving growth and foliage color of the trees. Yields were not larger than in 1932.

Yields are higher on nitrogen plots than on phosphorus–potash plots. The addition of potash to nitrogen seems to have increased yields after a year or two following the first application, and these increases have been greater during the past two years. There is as yet no indication that the addition of phosphorus to nitrogen and potash has improved yields.

Study of Varieties of Tree Fruits. (J. K. Shaw and O. C. Roberts.) The single tree of Macoun produced its first real crop at the age of nine years. The fruit is of excellent quality and less subject to scab than McIntosh; not so attractive in appearance, but of good size. The variety will probably prove an annual bearer and is promising for trial, but may not prove as productive as might be wished. It is possible that other more desirable candidates for the place of the much desired "Winter McIntosh" may appear. One of these possibilities is Kendall of which several trees were planted and a considerable number budded in the nursery.

Golden Delicious fruited well and is regarded as a promising variety. The quality of the fruit is unsurpassed among winter varieties and the yellow color should not prove a serious handicap. It may be recommended for plantings in a limited way for local markets, but will be more successful in regions where the season is longer and the atmosphere less humid, and this may prevent it from becoming an important variety in New England. It is quite resistant to most insects and diseases. The fruit russets easily from spraying, is easily bruised, and must be stored in high humidity.

Milton has proved to be often of undesirable shape and we now regard Early McIntosh as more desirable than Milton.

Richared is more attractive in appearance than Starking and may prove more desirable when a red type of Delicious is desired.

The early red varieties of Yellow Transparent season from the United States Department of Agriculture bore light crops. Further trial is necessary to indicate which ones are best, but it is felt that among these there are some that will prove desirable as early varieties for Massachusetts.

Diadem, a red winter apple from New Zealand bore a good crop of attractive apples of good quality and may prove worthy of further trial.

As the severe winter killed all the peach buds no further notes on the new peach varieties are available. There were no outstanding differences in hardiness of the wood though Golden Jubilee, Primrose, and Cumberland seemed a little less hardy and Halehaven and New Jersey No. 71 a little more hardy than other varieties.

Wright's Early Plum, a hybrid received from the United States Department of Agriculture proved hardier than Red June and Beauty, two other similar varieties of practically the same season. A good crop was produced and this variety is considered promising as an early plum of good quality. It ripens with us during the last ten days of July.

Several varieties of grapes originated at the New York Station are under observation. Fredonia continues promising as a substitute for Moore's Early. It is productive and early with well filled bunches. Seneca was severely injured by the unusual cold, though it has proved hardy in ordinary winters. It is early, of excellent quality, and keeps well in storage.

Portland and Ontario are both valuable varieties of early white grapes. Berries of Portland are larger but we consider those of Ontario of better quality. Both varieties shell rather badly.

The Newburgh raspberry continues practically free from mosaic though growing near other varieties badly infected. The plants are moderately vigorous and the berries large, attractive, firm, and of good quality.

Monroe is a good plant maker, early and productive. The berries are medium in size, attractive, and of excellent quality. It is somewhat subject to mosaic diseases.

The plants of Chief are healthy and very vigorous, resistant to mosaic, early, and produce heavily. The berries are rather small but of good quality.

Viking suffers from mosaic and winter injury but healthy plants produce heavily. The berries are of good size and quality, and attractive in appearance.

Lloyd George shows some tendency to be everbearing but is not reliable in this characteristic. It is subject to mosaic and blight. The berries are very large, of good quality, and of attractive appearance.

A considerable number of new strawberry varieties are under observation but further trial is desirable before comments are made.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter.) This project has been concluded and data are being prepared for publication. It was undertaken six years ago to study the effect of nitrogen applications on the formation of fruit buds, particularly when applied near the time of fruit bud formation.

No consistent effect has been found in repeated trials involving hills, placed runners with plenty of room, and moderately filled matted rows; and no consistent effect has been found either on a good strawberry soil or a soil that needed fertilization to produce satisfactory grain crops. All plots were duplicated five times and all plots received phosphorus and potassium.

Bud Mutation. (J. K. Shaw and W. H. Thies.) The trees topworked to various suspected bud sports made a satisfactory growth and should begin to bear in a year or two and show to what extent the variations shown in the original tree are transmitted.

Storage of Apples Under Various Conditions. (O. C. Roberts cooperating with Agricultural Engineering Department.) The two projects on storage reported on last year were continued, namely:

1. *A study of the effect of humidity on the keeping quality of apples at 32° and 45°F.* Additional data tend to support the assumption that the maintenance of high humidity at the lower temperature is less important than at the higher.

2. *The storage of McIntosh apples above 32°F.* Repeated tests indicate rather conclusively that if McIntosh apples are held at 45°F. for a period of two weeks after harvesting and are then subjected to decreasing temperatures until 32° is reached about November 1, the apples will be superior in flavor to those held at 32° continously and can be expected to keep satisfactorily until January 1 or a little later.

Tests of Various Spray Materials. (O. C. Roberts cooperating with Entomology and Botany Departments.) For another season tests of various spray materials have been made in the college orchards to determine their efficiency and safety to the trees and fruit. Results for the past season are given in the report of the Entomology Department.

Removal of Arsenic and Lead Residues from Apples. (O. C. Roberts and J. K. Shaw cooperating with Entomology and Agricultural Engineering Departments.) Apples which had been sprayed with lead arsenate were washed three to five minutes in the washer designed by Prof. Gunness, using a solution containing 1.3 percent HCl at 50° to 55°F. The removal of both arsenic and lead residues was highly satisfactory and the fruit suffered no apparent injury because of this washing process.

Blueberry Culture. (J. S. Bailey.) The half-acre planting set for cultural experiments is situated in a relatively low spot. During the winter of 1933-34 all of the bushes were killed practically to the snow line. The dead parts of the bushes were removed in the spring of 1934. This required very heavy pruning. However, the plants recovered and made an excellent growth during the summer.

In the spring of 1934 an experiment was started in Wagner pots using a sandy loam soil which had received no fertilizer for forty-five years. Treatments consisted of varying amounts of lime, 0 to 40 grams per pot, and varying amounts of sulfur, 0 to 40 grams per pot, both with and without peat added to the soil. Plants made the best growth in the pots receiving 5 grams of sulfur. Growth was increasingly poorer with increased amounts of both sulfur and lime until with the higher amounts the plants died. The soil used in this experiment is known to be deficient in potash. Tests of the soils in the pots revealed little or no available potash where lime was applied but relatively large amounts where sulfur was used.

The propagation work was continued. A test of German peat and a 50-50 mixture of sand and German peat indicated the German peat to be the better propagating medium. A higher percentage of rooted cuttings was obtained under burlap shade alone than under burlap shade and glass sash.

DEPARTMENT OF POULTRY HUSBANDRY

J. C. Graham in Charge

Broodiness in Poultry. (F. A. Hays.) Particular attention is now being given to the problem of deferred broodiness beyond the first laying year. Data published in Bulletin 301 indicate that genetically non-broody strains can not be established without testing both males and females for genetic purity for the recessive non-broody genes. A few aged males and a number of aged females are now on hand that are believed to breed true for non-broodiness. Progress is also being made in the study of inherited degree of broodiness. The flock as a whole has fallen to a new low level for broodiness.

Breeding Poultry for Egg Production. (F. A. Hays and Ruby Sanborn.) Such physical defects as light plumage color, white ear lobe, stubs, and wavy or lopped comb are being given special consideration in the flock. Broodiness has fallen to a new low level, and egg size has reached a level above 24 ounces for the year. Range mortality is low, but laying-house mortality runs high. The production-bred birds are very heavy in weight and exceed standard requirements for the breed. Fecundity characters are being maintained and production is high with good hatchability.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn.) Data have been prepared under this project and published as follows: "Breeding for Egg Production," Bulletin 307; "Character of Female Offspring of Rhode Island Red Inbred Males Compared with Female Offspring of Non-Inbred Males," *Poultry Science* (in press); "Effects of Inbreeding on Fecundity in Rhode Island Reds," Bulletin 312; and "Time Interval to Standard Egg Weight in Rhode Island Red Pullets," Bulletin 313.

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) A report on a five-year study of crosses between production and exhibition birds in relation to plumage color and fecundity characters is ready for publication. Birds are being bred for color alone, and a line of exhibition-bred birds is being bred for high fecundity. More detailed study is now being given to the component parts of Rhode Island Red plumage color.

Determination of Genetic Laws Concerning Results of Inbreeding. (F. A. Hays.) This project has been terminated and the results published in Bulletin 312.

Factors Affecting Egg Weight and Shell Character in Domestic Fowl. (F. A. Hays.) For the mating season of 1934, breeding females were selected on the following bases: Line 1, pullets reaching 24-ounce egg weight in 61 to 90 days; Line 2, pullets reaching 24-ounce egg weight in 31 to 60 days; Line 3, pullets reaching 24-ounce egg weight in 0 to 30 days. Previous to this the selection of breeding pullets was on the ability to lay 52-, 57-, or 59-gram eggs, respectively, for the month of December. Full brothers are still used in the three mating pens. Characteristic size, shape, and color of eggs has been studied in the three lines and the results will soon be interpreted and published.

Rate of Feathering in Rhode Island Reds. (F. A. Hays.) Preliminary studies have been carried on, on all pedigreed chicks since 1931. In the spring of 1934 two males that were completely feathered in the back region at eight weeks of age and two males with backs bare at eight weeks were used for breeding. All progeny was classified at eight or nine weeks of age for early or late feathering. Results to date indicate that autosomal genes are concerned in the rate of feathering in Rhode Island Reds.

Breeding for Low Mortality. (F. A. Hays.) An attempt is being made to establish by selective breeding a line of birds with very low mortality rate in the laying houses and a second line with very high mortality. In the spring of 1934 one male was selected from a family with low mortality and another male from a family having extremely high mortality. These two males were each mated to a pen of females, part of which were classed as low in mortality and part as high in mortality on the same basis that was used in selecting the males. Resulting progeny are now being carried through the year.

Breeding for High and Low Resistance to Fowl Paralysis. (F. A. Hays, C. S. Gibbs, W. C. Sanctuary and J. H. Vondell.) This is a cooperative project between the Departments of Poultry Husbandry and Veterinary Science, and was undertaken in the spring of 1933 to discover whether inheritance plays a part in resistance to fowl paralysis. Selection of breeding stock was based either on the incidence of paralysis in the family or on its incidence in the offspring. Three lines were established using two males with high incidence and one with low incidence. On the female side each line included both hens and pullets with high or low incidence of paralysis.

The first generation progeny hatched in 1933 was carried as a whole up to December when part of the males were discarded and the females retained. All sick or dead birds were carefully studied for pathological symptoms. The second generation hatched in 1934 was sired by cockerels from the three lines mated in part to the original females and in part to first generation females. Progeny are being handled in the same way as the first generation.

General results indicate the more frequent occurrence of paralysis from the high incidence matings.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, D. M. Yegian, O. S. Flint, and M. K. Clarke.)

1. *Pullorum Disease Eradication.* During the past year the Massachusetts poultrymen have shown an interest in pullorum disease testing and eradication which is equal to that of the previous season. This fact is encouraging, since economic conditions were markedly unfavorable to the poultry industry.

During the past testing season 262 flocks were tested, representing 263,241 tested birds, 284,848 tests, 0.53 percent positive tests, 229 negative flocks, and 33 positive flocks. As the result of testing over a period of years, great progress is revealed by the fact that the number of flocks which had been tested for three or more consecutive years was equal to 178, representing approximately 86 percent of the tests, of which 0.34 percent were positive. Only 11 of the 178 flocks were classified as infected, which shows that, through annual testing supplemented by effective preventive measures, flocks can be maintained free from pullorum disease. The primary object is to maintain the flocks free of the disease and to establish additional clean flocks through closely supervised testing and supervised replacements from known free flocks.

2. *Pullorum Disease Investigations.* Investigations to determine the role which feces from positive reacting birds may play in transmitting pullorum disease have revealed interesting results. Adult birds from a pullorum disease free flock, which were negative to the agglutination test, failed to contract pullorum infection when feces from infected birds were added to the litter at frequent intervals for a period of approximately one year. However, when non-infected birds were force-fed feces from infected birds evidence of transmission was obtained. While some phases of the complex problem of dissemination of pullorum infection have been studied, the transmissibility of this disease among adult stock requires further study in order that certain types of outbreaks may be prevented. Due to the lack of knowledge concerning this particular subject, poultrymen may not be exercising sufficient care in establishing and maintaining a free flock.

The ability of *S. pullorum* to remain viable on a dry piece of cloth is being studied. At the present writing the organism has remained alive for 855 days.

Investigations mentioned here are still in progress and will be reported in detail elsewhere.

3. *Laboratory Diagnoses.*

(a) Personal calls at the laboratory were recorded 127 times. The number of cases handled was 369. The classification of 1393 specimens follows:—1279 chickens, 30 turkeys, 28 ruffed grouse, 20 ducks, 16 pheasants, 6 canaries, 6 cattle, 3 sheep, 3 swine, 1 cat, and 1 mink. The diseases encountered most frequently were pullorum disease, parasitism, reproductive system disorders, so-called "range paralysis," tumors, kidney disorders, and proventriculitis. The diagnoses of diseases which are believed to be rather rare in Massachusetts were paratyphoid, fowl cholera, fowl typhoid, intestinal capillariasis, and pullorum disease in turkeys.

(b) Paratyphoid infections were encountered in chicks, ducks, and canaries. The outbreak in chicks received considerable study, which has not been completed.

(c) The pullorum disease in turkeys was traceable to hatching eggs in an incubator with eggs from an infected flock of chickens.

(d) *Dispharynx spiralis* infestation of ruffed grouse was noted in one young, wild bird. The other grouse were all young birds and came from one small flock. Kidney disorders and "slipped tendons" were prominent in necropsies.

(e) An acute condition affecting high-producing pullets came to our attention. Sporadic cases have been noted annually for the past few years. The histories of outbreaks in flocks present the following: condition excellent when housed two to four weeks previously, production 30 to 50 percent, feed consumption high, one or two dead birds found on roosts, a few birds depressed and weak on legs, and production drops markedly. Many of the depressed birds improve and resume production in two to four weeks, while others go into a neck molt. Approximately 10 percent was the highest mortality reported. Necropsy findings include a slightly enlarged liver with numerous yellowish foci, petechia on abdominal fat, pericardium, and pleura, and slightly enlarged pale kidneys. Aerobic and anaerobic bacteriological examination and transmission trial with liver emulsions and with blood were negative.

4. *Farm and Station Bang Disease.* In assisting this project, the laboratory tested 1,545 blood samples by the standard tube agglutination method.

Experiments on the Vaccination of Baby Chicks Against Infectious Laryngotracheitis. (C. S. Gibbs.) Practical poultrymen have frequently asked about the possibility of vaccinating chickens against infectious laryngotracheitis at the time they are removed from the incubator. An attempt has been made to do this experimentally, and it has been found that when the regular field vaccine was used 80 percent of the chickens died of acute infection of the cloaca and Bursa of Fabricius. For the successful vaccination of baby chicks, an attenuated virus of uniform virulence must be used; and since no practical way of producing such a standard virus has been discovered, it is impossible to successfully vaccinate baby chicks on a large scale against infectious laryngotracheitis.

Experiments with chickens at other ages indicated that they were not able to withstand the field vaccine until they were two months of age, and the best results were secured at three and four months of age.

Serological Experiments with Infectious Laryngotracheitis Virus. (C. S. Gibbs.) The elementary bodies occurring in the epithelial cells of the larynx and trachea of birds sick or dying of infectious laryngotracheitis may be liberated to a limited extent by grinding the exudate in 10 percent NaOH solution in an unglazed mortar with an unglazed pestle for half an hour or longer. After allowing the cellular debris to settle, the supernatant fluid is decanted into a centrifuge tube and centrifugalized at 3200 revolutions per minute until a clear, supernatant fluid is obtained. The supernatant fluid is carefully pipetted off, the tube refilled with carbolyzed saline, and shaken. The washing is repeated three or four times, after which the tube is centrifugalized at a moderate speed of 1200 or 1500 revolutions per minute to throw down as much of the cellular material as possible without interfering with the free elementary bodies. Unless an opalescent fluid is obtained the grinding, washing, or both have not been properly done. By adding an appropriate amount of immune serum to a properly prepared suspension of elementary bodies a flocculation test may be obtained which is specific for infectious laryngotracheitis, and not for normal serum, or the serum of birds suffering from pullorum disease, fowl typhoid, chicken pox, avian paralysis, or leukosis. Sometimes a slight flocculation occurs in the first supernatant fluid after the first washing, but it has never been found in the fluids of the other washings.

The elementary body suspension will bind complement, when it is properly prepared and balanced in a hemolytic system consisting of sheep's corpuscles, rabbit serum amboceptor, and guinea pig complement. Because of technical difficulties in preparing the antigen, these serological tests have not found any practical use in the control of infectious laryngotracheitis, but they are of scientific interest, because they support the view of Seifried and Burnet that these bodies are the virus of this disease.

Infectious Laryngotracheitis Virus in Eggs. (C. S. Gibbs.) Infectious laryngotracheitis virus has been passed through a series of graded acetic cellodion filters, and the filtrate inoculated into eggs. It has been found that the chorio-allantoic membrane of the egg may be affected by the virus and the embryo killed in three to five days. In no instance has the virus been carried through the incubation period of the egg. Virus introduced into eggs at the beginning of the incubation period, before the chorio-allantoic membrane is formed, does not live longer than 24 hours in the incubator, but may live longer than 24 hours if the egg is kept in cold storage. Small quantities of the virus-filtrate introduced into the air sac during the last week of incubation do not infect the embryo. Large quantities of the liquid kill the embryo, but it appears to die of causes other than infectious laryngotracheitis. It is believed that these studies have been advanced far enough to indicate that the danger of transmitting infectious laryngotracheitis through the egg is remote.

Comparative Studies of Toisson's Fluid and Hayem's Fluid Containing 2 percent Eosin for Counting Erythrocytes and Leukocytes in Avian Blood. (C. S. Gibbs, R. F. Sturtevant, K. W. Chapman, and C. G. Johnson.) Hayem's fluid containing 2 percent eosin is superior to Toisson's fluid in that there is less clumping of the cells, and less danger of the stain precipitating during a count and thus making it necessary to repeat the process with fresh stain. A higher leukocyte count is obtained with Hayem's fluid than is secured with Toisson's fluid with the same blood under the same conditions. Therefore, Hayem's fluid is preferable to Toisson's fluid in counting avian blood cells.

The Oxydase Test in Avian Pathology. (C. S. Gibbs and K. W. Chapman.) Oxydase tests on representative samples of leukemic and normal avian blood were made by the Graham, Goodpasture, Washburn, and Sato and Sekiya's techniques. The method of Sato and Sekiya was found superior to the others from the standpoint of the keeping qualities of the stain, and the rapidity of staining. If the sole object is to determine the number of cells containing oxydase granules in a given smear of avian blood, then Sato and Sekiya's technique should receive first choice. But if it is desired to make a complete differential count of all cells in a smear, then Washburn's technique should be selected on the basis of this study, because it is the only stain that will answer the purpose. The oxydase test was found to be of value in differentiating leukemic from non-leukemic avian blood.

Leukosis and Avian Paralysis. (C. S. Gibbs and C. G. Johnson.) Myeloleukosis and to a lesser extent erythroleukosis may be transmitted by direct inoculation of affected blood into healthy chickens, by contact infection, and by inoculation into eggs in which the bone marrow cells of the embryo have been formed. Lympholeukosis, monoleukosis, and neurolymphomatosis are not readily transmitted by inoculating either affected blood or diseased tissues into healthy chickens and fertilized eggs. The experimental data thus far indicate that neurolymphomatosis in particular is transmitted naturally through the egg. Direct transmission from fowls having diseased ovaries has been observed in a few instances, but in most cases the method of transmission is obscure, indicating that further work must be done before the pathology of this disease is understood.

Field experiments indicate that mortality from both leukosis and avian paralysis may be reduced by removing diseased birds from the flock as soon as symptoms are noticed and so disposing of them that they can never get into the flock again. For reasons which are not understood at present, this method of control is more effective for neurolymphomatosis than it is for myeloleukosis and erythroleukosis.

Proventriculitis and Ventriculitis. (C. S. Gibbs and K. L. Bullis.) A necrotic disease of the tissues lining the proventriculus and the ventriculus has been noted at this station for some time. Attempts to determine the cause of this condition have been unsuccessful in that significant microorganisms have not been isolated. Finally, one of us suspected that it might be due to paralysis of the nerves supplying these organs. Since then considerable data have been collected, indicating that one cause, if not the sole cause, is paralysis of important branches of the vagus and coeliac nerves which supply these organs. Apparently, proventriculitis and ventriculitis are but further manifestations of avian paralysis.

Infectious Coryza. (C. S. Gibbs and K. L. Bullis.) Next to leukosis and avian paralysis, infectious coryza is the most baffling of any of the diseases of poultry from the standpoint of etiology and control. If the disease occurred as a filterable virus or a bacterial infection alone, the problem of differential diagnosis and control would be greatly simplified. But the investigations at this station and others thus far indicate that infectious coryza is invariably complicated,—filterable viruses of the common cold, infectious laryngotracheitis, and chicken pox of low virulence, and avitaminosis being the primary factors, which lower the resistance to bacterial infection of varying character to complicate the disease picture and the method of treatment. Furthermore, the bacterial factors in different outbreaks appear to vary in kind and virulence, and with respect to locality, season, and breed. In some instances, as in the case of *Hemophilus coryza gallinarum* and some forms of streptococci, they have been found to assume a primary etiological role, independent of viruses and deficiency diseases.

The greatest need at the present time is for practical diagnostic tests by which the various forms of infectious coryza may be differentiated and specific treatments applied. Attempts to discover such tests have been pursued throughout the year in connection with the Diagnostic Service. The serological tests for infectious laryngotracheitis reported above, the adaptation of the Nelson technique for the isolation and study of *H. coryza gallinarum*, and the use of Rosenheim's and Drummond's test for vitamin A deficiency in cases of infectious coryza are some of the methods that have been used in the attempt to solve this problem.

WALTHAM FIELD STATION
(Waltham, Massachusetts)

Ray M. Koon in Charge

For reports on approved projects conducted at this station, in addition to those listed under this caption, see reports of the Departments of Botany, Entomology, Floriculture and Olericulture.

Along with its function as a research unit of the college, this station has continued to develop and advance in its usefulness as a center of information because of its proximity to a dense population of varied horticultural interests. During the past year there has been a marked increase in the number of telephone inquiries, requests for printed information, and visitors who have come to consult the several members of the staff.

The Boston Market Gardeners Association has continued to use the station as headquarters for their monthly executive committee conferences and have contributed much in the way of suggestions for worth-while projects. The Field Station staff has, as usual, arranged the program of seven educational meetings which the Market Gardeners Association holds during the winter months.

The Sixteenth Annual Field Day was held on August 1 with a record attendance. Over 1100 farmers and others engaged in activities relating to farming visited the Field Station during the day, testifying to the interest in progressive horticultural practices. Despite the exceptionally dry season, the demonstration and experimental plots were in good condition for inspection.

The Plant Houses. (P. W. Dempsey.) Continued interest in this project is evidenced by the number of visitors who come to the Field Station especially to examine the plant houses, and the steady demand for plans by mail. Both houses were successfully operated during the past severe winter, proving them practical for operation the year around if desired.

Electricity as a Source of Heat in the Hotbed and Propagating Bench. (P. W. Dempsey.) Very little interest in electrical heat has been shown during the past year by commercial growers or amateurs. Growers have been very slow even to give the method a trial, perhaps because of a prevailing belief that electricity as a source of heat is excessively expensive. It may also be due to the possibility of failure of continuous service because of storm or breakdown. Even in places where power companies have supplied equipment and current free of charge for demonstration, growers are still using their former methods.

Users of this equipment cannot afford to pay more than 3 cents per kwh. for electricity either in the hotbed or propagating bench. At this rate, the cost of the Field Station hotbeds has averaged $1.75 per sash (3 ft. x 6 ft.), March 1 to May 15; and the cost of the propagating benches has averaged 1 cent for each running foot of bench (3 feet wide) for each 10° above air temperature each 24 hours.

Vegetable Variety Trials. (P. W. Dempsey.) The sweet corn trials this year were associated mainly with the new hybrid, topcrossed, and inbred strains, especially regarding their resistance to the Stewart's Disease so threatening last year. Owing to the absence of the disease this year no resistance records could be taken, but a good opportunity was afforded for observation of other variety characteristics. These new crosses are superior to their parents in yield and uniformity and all are of excellent quality. Unfortunately, they are considerably later than the original varieties. The future alone will determine to how great an extent these new strains will replace the older varieties.

Although the tomato trials each year include a number of new strains, there is still need of a good early tomato. Marglobe has its place as a standard midseason and late variety, but growers are still looking for a satisfactory early variety. Abel, Bestal, Lincoln, Harkness, and Early Lightening were tried this year for the first time and will require another season's trial before definite recommendations can be made. As many Massachusetts growers are particularly interested in trellis tomatoes now, an earnest effort is being made to produce a superior strain for this purpose. The Field Station Comet has proved satisfactory in the hands of growers throughout the State both in the greenhouse and on the trellis outside.

Ornamental Display and Test Gardens. (Harold E. White.) Public interest in the ornamental gardens since they were established in 1931 has increased to such an extent that it has become necessary to have an attendant on duty in the evenings from 5 to 8 o'clock during June, July, August, and September. Records kept of evening visitors alone through these months show a total of 1425. The best of the new perennials and many of the worthy older ones are added from time to time. All the plants are clearly labeled and a list of sources from which the plants may be obtained is available at the office.

Horticultural Schools. (Harold E. White.) The horticultural schools initiated four years ago are of two types. The one is designed to provide florists with cultural information derived particularly from research. The other is an answer to a request from home gardeners who desire instruction regarding the beautification of their home environment. Each school is held for two days, and the continuing interest can be gauged by the attendance of 150 commercial florists and 483 home gardeners this year.

Consultation Service. The demand for information on the part of the general public has become so pressing that it has been necessary to appoint one member of the staff to take care of this work and to some extent relieve the other members of the extra burden of constant interruption by visitors and telephone calls. Paul W. Dempsey, who has been in charge of the field work of the station since its establishment in 1917, has been appointed Assistant Research Professor of Horticulture to take care of this important part of the work. This service includes interviews with commercial vegetable growers and amateur gardeners, testing of soil and making recommendations, giving talks on horticultural subjects to organizations which request them, guiding visitors about the Field Station, and consulting with representatives of commercial concerns and other individuals seeking information about their products.

PUBLICATIONS

Bulletins

305 Annual Report for the Fiscal Year Ending November 30, 1933. 68 pp. March, 1934.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

306 Fertilizer Tests on an Important Pasture Soil Type. A. B. Beaumont. 12 pp. illus. January, 1934.

In order that the results from previous investigations regarding the use of commercial fertilizers on permanent pastures might find more specific and wider application, the work was carried into other sections of the State for trial and demonstration on a different soil type. This bulletin presents results from that work.

307 Breeding for Egg Production. F. A. Hays and Ruby Sanborn. 28 pp. April, 1934.

During the past twenty years the Poultry Husbandry Department has conducted numerous investigations to determine the influence of various factors, controllable through breeding, on the egg-producing ability of Rhode Island Reds. This bulletin is a compilation of results obtained up to the present date, and is intended as a guide to assist the poultry breeder in directing his operations.

308 Preliminary Studies on Neurolymphomatosis and Some More or Less Related Diseases. Charles S. Gibbs. 32 pp. illus. May, 1934.

Neurolymphomatosis, generally referred to as "fowl paralysis" has been recognized in Massachusetts for many years. All breeds of chickens are susceptible. The clinical course of the disease varies in individual cases, usually extending over a period of several weeks or months. Complete recovery is rare. Temporary improvement may occur followed by relapse and death. The pathological cell appeared to be the same in neurolymphomatosis and lymphocytomatosis, but the former is primarily a disease of young birds from 3 to 10 months of age, while the latter is more common in birds 10 months of age or older. On the basis of the experimental data secured in these studies, these diseases may be controlled by eradicating affected birds from the flock as soon as noticed, adopting the best sanitary procedures, and increasing the vigor of the birds by judicious breeding.

309 Soybeans for Massachusetts. A. B. Beaumont and R. E. Stitt. 16 pp. illus. May, 1934.

The greatest promise of the soybean in New England lies in its possibilities as a forage crop. It can hardly compete with the grasses, clovers, and alfalfa as a principal source of forage; but as a more or less temporary or emergency leguminous forage crop, it has distinct advantages. Twenty varieties were tested for yield of hay for the three-year period 1929-1931, and in two of the years yield of seed was also obtained. The bulletin describes the varieties and the results obtained with each, and also includes a discussion of the uses of soybeans and the best methods of culture.

310 Supplementary Mid-Morning Feeding of Rural School Children. Bernice Wait, Oreana Merriam, and Madaline V. Cowing. 48 pp. illus. June, 1934.

The effects of giving a mid-morning lunch to children have been studied in four rural elementary schools which involved some 760 children. The lunches consisted of pasteurized milk, reconstituted evaporated milk, tomato concentrate, and a mixture of evaporated milk and tomato juice. There is included a full description of the methods used and the difficulties encountered in trying to measure the effect of the various lunches on the condition of the children. A definite though not marked improvement in the children seemed evident with the feeding of milk, whether pasteurized or evaporated, or a mixture of milk and tomato. Much less improvement was indicated with the feeding of the tomato concentrate, though the difference would probably have been less had as much tomato as milk been given. Improvement was noted in the children who were in good condition as well as in those who were in fair or poor condition at the beginning of the study.

311 Infectious Laryngotracheitis Vaccination. Charles S. Gibbs. 20 pp. illus. July, 1934.

The loss from infectious laryngotracheitis in poultry flocks in the State of Massachusetts is a matter of much economic concern. An interest in the control of this disease has resulted in field and laboratory experiments to develop a satisfactory method of producing immunity through vaccination. This bulletin reports a method of preparing and using autogenous vaccines which has proved satisfactory in both laboratory and field tests. It should be understood that this method of vaccination will save the flock if properly applied, but cannot be depended upon to eliminate carriers, and it should therefore be followed by complete eradication and sanitary control of the disease. Vaccination for infectious laryngotracheitis merely enables the poultryman to choose the time for disposing of the birds and cleaning and disinfecting the premises occupied by them. When accepted in this light, vaccination is a valuable contribution to the control of infectious laryngotracheitis.

312 Effects of Inbreeding on Fecundity in Rhode Island Reds. F. A. Hays. 8 pp. October, 1934.

Inbreeding has been used extensively for establishing uniformity in herds and flocks. This report covers the results of inbreeding poultry for high fecundity characters when rigid selection of female breeding stock was practiced. In no respect were the inbreds or inbreds crossed found to be superior to the general flock. Apparently nothing is to be gained from the standpoint of fecundity by inbreeding.

313 Time Interval from First Egg to Standard Egg Weight in Rhode Island Red Pullets. F. A. Hays. 12 pp. October, 1934.

In breeding for egg size an important consideration is the time required by pullets to attain 24-ounce egg weight. This report is concerned with a number of factors that vitally influence this time interval. Analysis of the data showed that about 58 percent of the variation in time to standard egg weight was due to variation in the following: hatching date, age at first egg, weight at first egg, winter clutch size, winter pause, broodiness, and persistency; while the other 42 percent was probably due to unknown hereditary factors. In breeding to increase egg size, it seems advisable to select breeding females exclusively from those which attain standard egg weight in less than 75 days after the first pullet egg.

314 Effect of Aging Treatment on the Bacterial Count of Ice Cream Mixes. W. S. Mueller and R. L. France. 8 pp. October, 1934.

This investigation was undertaken to determine whether the aging temperature of 68°F., considered desirable when gelatin is used in the manufacture of ice cream, has an unfavorable effect on the bacterial count of the product. The following results were secured:

The aging of pasteurized ice cream mixes for 6 hours at 68°F., whether followed by aging for 18 hours at 38° or not, did not result in a significant increase in the number of bacteria present; but similar aging of unpasteurized mixes did materially increase the number of bacteria. When a pasteurized ice cream mix was aged for 24 hours at 68°, a definite increase in the bacterial count did not occur until after the tenth hour; and when held for 24 hours at 38°, no material increase occurred.

Control Bulletins

72 Seed Inspection. F. A. McLaughlin and Margaret E. Nagle. 47 pp. February, 1934.

73 Fourteenth Annual Report on Eradication of Pullorum Disease in Massachusetts. Poultry Disease Control Laboratory. 8 pp. October, 1934.
74 Inspection of Commercial Fertilizers. H. D. Haskins. 54 pp. November, 1934.
75 Inspection of Commercial Feedstuffs. Philip H. Smith. 55 pp. December, 1934.
76 Inspection of Agricultural Lime Products. H. D. Haskins. 8 pp. December, 1934.

Meteorological Reports

541-552, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. C. I. Gunness. 4 pp. each.

Reports of Investigation in Journals

(Numbered Contributions[1])

168 Variability in Development of Fresh-Laid Hen Eggs. F. A. Hays and Costas Nicolaides. Poultry Sci. 13:74-80. March, 1934.
176 Control of the Verticillium Wilt of Eggplant. E. F. Guba. Phytopath. 24:906-915. August, 1934.
178 The Absorption and Evaporation of Moisture from Plant Containers. Linus H. Jones. Jour. Agr. Research 48:511-516. March 15, 1934.
179 The Relation of "Dark Center" to the Composition of Rutabagas. E. B. Holland and C. P. Jones. Jour. Agr. Research 48:377-378. February 15, 1934.
181 Some Observations on Long Distance Dispersal of Apple Maggot Flies. A. I. Bourne, W. H. Thies, and F. R. Shaw. Jour. Econ. Ent. 27:352-355. April, 1934.
182 The Apple Leaf-Curling Midge, a New Pest of Apples. W. D. Whitcomb. Jour. Econ. Ent. 27:355-361. April, 1934.
183 An Unusual Leaf Variation of the Apple. A. P. French. Amer. Soc. Hort. Sci. Proc. 30:143-146. 1933.
184 Preliminary Report on Breeding Rust Resistant Snapdragons. Harold E. White. Amer. Soc. Hort. Sci. Proc. 30:589-590. 1933.
185 The Relation of the Carbon-Nitrogen Ratio of a Mulch to the Accumulation of Nitrates in Soil. W. J. Moore, Jr., and A. B. Beaumont. Jour. Amer. Soc. Agron. 26:252. March, 1934.
187 Corynebacterium Infection in Poultry. Diran M. Yegian. Jour. Amer. Vet. Med. Assoc. 85 (n. s. 38):220-223. August, 1934.
189 Sexing Baby Chicks. Charles S. Gibbs. Poultry Sci. 13:208-211. July, 1934.
190 The Forms of Nitrogen in Infusions of Corn, Timothy, Red Clover, Tobacco, and Red Top. Walter S. Eisenmenger. Jour. Agr. Research 49:375-378. August 15, 1934.
191 A Proposed Classification of the Chemical Elements with Respect to Their Functions in Plant Nutrition. R. W. Thatcher. Science 79:463-466. May 25, 1934.
192 Why Dandelions? Emmett Bennett. Science 80:142. August 10, 1934.
193 Gelatin in Ice Cream Specialties and How It Should Be Used. W. S. Mueller and J. H. Frandsen. The Ice Cream Trade Journal, July, 1934.
195 Relation of Benzoic Acid Content and Other Constituents of Cranberries to Keeping Quality. J. A. Clague and C. R. Fellers. Plant Physiol. 9:631-636. 1934.

196 Controlling Physical Properties of High Solids Mixes. M. J Mack. Jour. Dairy Sci. 17:781-789. December, 1934.

201 The Evolution of Nutrition. J. G. Archibald. Jour. Chem. Ed. 11:601-608. November, 1934.

206 Using Frozen Sliced Strawberries in Manufacturing Ice Cream. M. J. Mack and C. R. Fellers. The Ice Cream Trade Journal, December, 1934.

207 The Effect of Some Forms of Nitrogen on the Growth and Nitrogen Content of Wheat and Rice Plants. Guy Thelin and A. B. Beaumont. Jour. Amer. Soc. Agron. 26:1012-1017. December, 1934.

[1] Nos. 169-174 were listed in the last Annual Report; Nos. 175, 177, 180, 186, 188, 194, 197, 198, 199, 200, 202, 203, 204, 205 have not yet been printed.

Other Contributions to Journals

(Unnumbered)

Apple Rust Up-to-Date. E. F. Guba. Mass. Fruit Growers' Assoc. Ann. Rpt. 40:48-52. 1934.

Slime Flux. E. F. Guba. Tenth Natl. Shade Tree Conf. Proc. 56-60. 1934.

Acidity of Potting Soil not Affected by Type of Container. Linus H. Jones. Florists' Review 74 (1904):9. May 24, 1934.

Advocate Use of Jardinieres over Pots to Conserve Moisture. Linus H. Jones and George A. Bourgeois. Florists' Review 74 (1915):9-10. August 9, 1934.

Plastic Cream, a New Dairy Product, is on the Market. M. J. Mack and C. R. Foskett. Food Industries 6:156-157. April, 1934.

How to Make High-Butterfat Ice Cream. J. H. Brockschmidt, M. J. Mack, and J. H. Frandsen. Ice Cream Field, January, 1934. pp. 16-18.

Orchard Insect Pests of 1933 in Massachusetts. A. I. Bourne and W. D. Whitcomb. Mass. Fruit Growers' Assoc. Ann. Rpt. 1934.

Notes on a Fungus Attacking Onion Thrips. A. I. Bourne and F. R. Shaw. Jour. Econ. Ent. 27:860. August, 1934.

The Economics of Bank Service Charges and Other Phases of National Recovery. R. L. Mighell and R. H. Barrett. (This is a mimeographed circular made up of 16 articles published in the Springfield Republican from December, 1933 to April, 1934.)

Banking "Cost Analysis." R. L. Mighell and R. H. Barrett. Consumers' Research General Bulletin. April, 1934.

The Bankers' Code and Service Charges on Checking Accounts. R. L. Mighell and R. H. Barrett. Consumers' Research General Bulletin. October, 1934.

Fundamental Nutritive Values of Apples. C. R. Fellers. Mass. Fruit Growers' Assoc. Ann. Rpt. 1934. pp. 181-184.

Sea Scallops—A Neglected Food Product. C. R. Fellers. Glass Packer 13:330-331. May, 1934.

Fermentation of Citron. C. R. Fellers and E. G. Smith. Jour. Bact. 27:63. January, 1934. (Abstract of paper before the Society of American Bacteriologists, December, 1934.)

Food Value of Cranberries and Cranberry Sauce. C. R. Fellers. Forecast 47 (No. 2). 1934.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
2500-4-'35. No. 4226.

40
16

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Bulletin No. 316 January, 1935

Crossing Production and Exhibition Rhode Island Reds

By F. A. Hays

Agri. Library
File No. 2

In this five-year study an attempt was made to determine whether, through crossing exhibition-bred and production-bred Rhode Island Reds, the characters necessary for high egg production might be retained without the sacrifice of plumage color.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

CROSSING PRODUCTION AND EXHIBITION RHODE ISLAND REDS

By F. A. Hays, Research Professor of Poultry Husbandry

INTRODUCTION

It is a widely recognized fact that production-bred Rhode Island Reds differ significantly from exhibition-bred birds of the same variety in a number of specific characters. Hays (1933), in a preliminary report, pointed out characteristic differences in fecundity characters. Another important question constantly before breeders of Rhode Island Reds is the relationship between plumage color and desirable fecundity traits.

This report includes the results of a five-year study in crossing production-bred birds with exhibition-bred birds. The character of the parental stocks is first considered and later the character of offspring from eight different types of hybrid matings. Attention is first given to fecundity traits and finally the behavior of plumage color is considered.

Production-bred stock was selected from the station flock bred for high fecundity since 1913. Exhibition-bred stock came from hatching eggs furnished in 1929 by one of the world's leading breeders. Hybrid offspring were hatched over a four-year period from 1930 to 1933.

CHARACTER OF PARENTAL STOCKS

In these studies females are classified as follows:

Early maturing—laying their first egg at 215 days of age or younger.

Highly intense—having a mean winter clutch size of 3 or more eggs.

Non-pause—showing no cessation in egg production as great as 4 days between Nov. 1 and March 1.

Non-broody—exhibiting no broodiness during the first laying year.

Highly persistent—laying for not less than 315 days from first pullet egg.

Other characters reported in Table 1 are of importance in production breeding.

Table 1 presents an interesting and valuable comparison between the parental stocks used for crossing in this experiment. A study of the two populations gives a general picture of the differences that are most likely to occur so far as fecundity or related characters are concerned.

Exhibition birds were heavier at first egg, but this difference was almost if not entirely due to their greater age. The production birds were decidedly superior in early maturity, the exhibition birds being characteristically late maturing. Production birds were greatly superior in intensity, only one bird of the exhibition group showing high intensity. The percentage of birds with winter pause was about the same in the two lines. Because of earlier maturity, the production birds laid for a much longer period during the winter season than did the exhibition birds, which gave greater opportunity for pause to occur in the production line. The mean egg weight from first egg to January first was considerably greater in the exhibition line. In the birds tested, hatchability was very much higher in the production line. The proportion of non-broody birds, measured by first-year records, was essentially the same in the two lines. The percentage of highly persistent birds was nearly three times as great in the production line as in the exhibition line. The mortality rate for 365 days in the laying houses was significantly higher in the production line. Mean annual egg production was about 207 eggs for production birds compared with 130 eggs for exhibition birds.

Table 1 shows in general that the production line was superior for early sexual maturity, intensity, hatchability, persistency, and annual egg production. The exhibition line excelled in egg size and for low laying-house mortality only. Differences in body weight at first egg are of questionable significance because of great differences in age at first egg.

CHARACTER OF HYBRIDS

Hybrids produced were derived from the following classes of matings:

1. Exhibition males X production females } F_1
2. Production males X exhibition females }
3. F_2 generation.
4. F_1 males X production females.
5. Production males X F_1 females.
6. Exhibition males X F_1 females.
7. Production males X F_2 females.
8. Exhibition males X F_2 females.
9. Miscellaneous hybrid matings.

Check birds include the general flock bred for high fecundity in the same year or years in which the different hybrid matings were made. All birds were hatched, reared, and housed together in order to reduce the effects of environmental influences. In Table 2 the data are summarized for comparative study. Some interesting differences are shown between the various classes of hybrids and the checks, which represent production-bred lines.

Class 1 hybrids, representing the F_1 generation from mating exhibition males to production females, were decidedly superior to the checks in body weight at first egg, showing the effects of heterosis. Early sexual maturity was observed in a greater percentage of the check birds than of the F_1 daughters, which accounts in part for the greater weight of the hybrids at sexual maturity. The hybrids were not quite equal to the checks in intensity, but there was very little difference between the two groups with respect to pause. Winter egg weight was decidedly greater in the hybrids, and their eggs averaged slightly over 24 ounces per dozen up to January 1. Of the birds tested, the hybrids were slightly superior to the checks in hatchability. The percentage of non-broody birds was somewhat less in the hybrids than in the checks. Persistency was decidedly lower in the hybrids, suggesting either that persistency was not well established in the production birds or else that dominant genes for low persistency were transmitted by the exhibition parents. Mortality rates in the laying houses were very similar in hybrids and checks, certainly not showing a difference great enough to be significant. In annual egg production the hybrids fell below the checks, due in large measure to greater age at sexual maturity, lower intensity, more broodiness, and greatly reduced persistency.

TABLE 1.--CHARACTER OF PARENTAL STOCKS HATCHED IN 1929

Class of Birds	Number of Birds	Mean Weight at First Egg, pounds	Number of Birds	Per cent Early Maturing	Number of Birds	Per cent Highly Intense	Number of Birds	Per cent Non-pause	Number of Birds	Mean Egg Weight to Jan. 1, grams	Number of Birds	Mean Hatchability, Per cent	Number of Birds	Per cent Non-broody	Number of Birds	Per cent Highly Persistent	Number of Birds	Laying House Mortality, Per cent	Number of Birds	Mean Annual Egg Production, eggs
Production line	177	5.48	178	82.02	165	35.76	165	33.33	164	50.08	18	81.95	114	86.48	114	71.05	186	27.42	114	206.57
Exhibition line	35	6.42	39	2.56	31	3.23	31	29.03	20	55.78	10	51.09	32	84.38	32	25.00	43	16.28	32	130.09
TABLE 2.--CHARACTER OF HYBRID OFFSPRING AND CHECKS																				
1. F_1—Exhibition males X Production females	64	6.27	64	67.19	64	54.69	64	65.63	62	57.14	6	88.00	52	46.15	52	38.46	64	18.75	52	197.65
Checks (1)	391	5.44	391	89.00	374	63.37	373	60.59	376	50.60	33	81.29	283	80.21	283	85.51	399	20.80	283	236.51
2. F_1—Production males X Exhibition females	22	6.67	22	81.82	22	40.91	22	63.64	21	56.21	2	79.41	19	73.68	19	57.89	22	9.09	19	207.74
Checks (2)	224	5.37	224	94.20	217	66.36	217	65.44	218	50.70	17	79.97	180	85.00	180	90.00	227	15.42	180	245.26
3. F_2 Generation	90	6.12	90	45.56	81	14.81	81	34.57	79	56.01	10	65.12	52	67.31	53	43.40	103	31.07	53	168.28
Checks (3)	406	5.66	406	84.48	391	57.03	390	56.67	390	52.15	33	75.72	276	85.51	276	83.70	420	23.81	276	235.04
4. F_1 males X production females	16	6.25	16	68.75	15	33.33	15	13.33	16	53.78	3	75.86	12	91.67	12	66.67	16	18.75	12	184.33
Checks (4)	224	5.37	224	94.20	217	66.36	217	65.44	218	50.70	17	79.97	180	85.00	180	90.00	227	15.42	180	245.26
5. Production males X F_1 females	61	6.45	64	56.25	56	60.71	56	62.50	53	55.03	7	66.54	28	75.00	28	64.29	71	50.70	28	228.68
Checks (5)	182	6.01	182	73.53	174	45.40	173	45.66	172	53.99	16	71.60	96	86.46	96	71.88	193	33.68	96	215.86
6. Exhibition males X F_1 females	16	5.80	17	47.06	16	18.75	15	53.33	14	55.79	3	60.40	7	57.14	7	14.29	21	28.57	7	175.57
Checks (6)	224	5.37	224	94.20	217	66.36	217	65.44	218	50.70	17	79.97	180	85.00	180	90.00	227	15.42	180	245.26
7. Production males X F_2 females	22	5.87	22	72.73	21	52.38	21	61.90	22	57.55	2	47.37	19	89.47	19	57.89	23	13.04	19	211.26
8. Exhibition males X F_2 females	11	5.75	11	45.45	10	0	10	30.00	9	54.77	2	40.58	9	55.56	9	22.22	11	18.18	9	171.67
9. Miscellaneous hybrid matings	39	6.14	39	82.05	38	42.11	38	42.11	38	56.36	5	52.04	30	76.67	30	40.00	42	21.43	30	198.73
Checks (7, 8 and 9)	182	6.01	182	73.53	174	45.40	173	45.66	172	53.99	16	71.60	96	86.46	96	71.88	193	33.68	96	215.86

Class 2 hybrids, representing the F_1 generation from mating production males to exhibition females, are comparable with class 1 hybrids produced by the reciprocal cross. The group of class 2 hybrids showed heavier weight at first egg along with a greater percentage of early maturing birds than appeared in class 1 hybrids. Class 2 hybrids showed lower intensity, somewhat lower hatchability, and a mortality rate about half that of class 1. Class 2 hybrids were equal to class 1 in freedom from winter pause and in winter egg weight, and were decidedly superior in freedom from broodiness, persistency, and to some extent in annual egg production. Class 2 hybrids compared with their checks showed almost the same differences that were observed between class 1 hybrids and checks, except that laying-house mortality was much lower in class 2 hybrids than in their checks.

Class 3 hybrids are the F_2 generation produced by mating of F_1 birds. In hybrid matings the F_2 generation shows the maximum variability because of segregation of characters. In such crosses as are considered in this report, the F_2 generation may be inferior to the F_1 generation because of segregation of undesirable genes and because of high variability in characteristics affecting fecundity.

Table 2 shows that the F_2 pullets were heavier than the checks at first egg but less than half of the birds were early maturing compared with 84.48 per cent early maturing in the checks. In comparison with the checks, F_2 birds were also decidedly low in intensity, showed more winter pause, larger winter egg size, lower hatchability, a decreased percentage of non-broody birds, lower persistency, increased mortality, and greatly decreased egg production.

Class 4 hybrids, produced by mating F_1 males to production females, were superior to the checks in body weight at sexual maturity, but their age at sexual maturity was greater and the percentage of genetically early-maturing birds lower. These hybrids were decidedly inferior to the checks in intensity, winter pause, persistency, and egg production; they were superior in egg weight, and about equal to the checks in hatchability, non-broodiness, and mortality rate. Compared with the first hybrid generation, they were superior only in freedom from broodiness and in persistency.

Class 5 hybrids represent the reciprocal type of mating to class 4; namely, mating production males on F_1 females. Daughters produced were somewhat heavier at first egg than check daughters and showed a significantly lower percentage of early-maturing individuals. They were superior to the checks in intensity, non-pause, winter egg weight, and annual egg production. The hatchability of hybrids and checks differed significantly and the percentage of non-broody birds was lower in the hybrids, but the laying-house mortality was very high. Compared with the hybrids of class 4, the class 5 hybrids were greatly superior in intensity and in the absence of winter pause, enabling them to average 229 eggs compared with 184 eggs for class 4 hybrids. Class 5 hybrids were decidedly low in vigor as judged by the high mortality rate in the laying houses.

Class 6 daughters came from crossing exhibition males on F_1 females. This generation of hybrids was inferior to their checks in all respects except winter egg size and body weight. They averaged to lay 176 eggs compared with 245 eggs for the checks. Compared with the daughters in class 5 where production males were mated to F_1 females, they were decidedly inferior except in vigor.

In class 7 the daughters of production males mated to F_2 females are considered. Compared with the checks, these females were smaller at first egg but showed the same percentage of early-maturing birds; they were slightly superior in intensity and non-pause, decidedly superior in winter egg weight, greatly superior in mortality, and equal in egg production, but were low in hatchability and in persistency.

Class 8, representing the daughters of exhibition males mated to F_2 females was not equal to class 7 daughters in weight at sexual maturity, and there was a much higher proportion of late-maturing birds. Class 8 contained no highly intense and very few non-pause birds, and was inferior to class 7 in egg size, hatchability, non-broodiness, high persistency, mortality rate, and egg production. Compared with the checks, class 8 birds were inferior in all respects except winter egg size and mortality rate.

Class 9 includes daughters from various types of matings not already considered. They were superior to the checks in body weight, sexual maturity, winter egg weight, and mortality rate; they were inferior in hatchability, non-broodiness, persistency, and annual egg production.

In general, Table 2 indicates that hybridization increases body weight, especially in the F_1 generation; that early sexual maturity dominates late sexual maturity; that high intensity depends on dominant genes; that winter pause is little affected by crossing; that winter egg size is increased; that hatchability is improved only in the first generation; that broodiness may be increased by hybridization; that persistency is lowered by crossing; that laying-house mortality is reduced only in the first generation cross; that annual egg production is above intermediate between the two parent stocks in the first hybrid generation and tends to decrease in the F_2 generation, but that production can be raised to a high level by back crossing F_1 and F_2 females on production-bred males.

PLUMAGE COLOR[1]

The general behavior of plumage color in the various crosses between the characteristically light-colored production fowls and the essentially bay-colored exhibition birds is of economic and scientific interest. Breeders often desire to darken the shade of red because of market demands but definite information on the behavior of color in inheritance is lacking. In Table 3 the surface color of males and females is listed separately for the exhibition stock and for nine different types of hybrid offspring. All records on plumage color were taken when the birds were from five to six months of age.

Surface Color

Table 3 presents a summary of the adult surface color of male and female hybrid offspring from ten different types of mating.

---

[1] It is a well-known fact that in many Rhode Island Red fowls the surface color and under color vary in different body regions. There is, however, a rather intimate association between shades of color in surface and feather fluff on the same bird in different body regions. For the sake of simplicity in this study the plumage color has been consistently considered only in the mid-back region which has been taken as representative of the plumage color in general. This method of procedure would seem to be justified by the studies of Warren and Gordon (1933).

TABLE 3.--DISTRIBUTION OF OFFSPRING WITH RESPECT TO SURFACE PLUMAGE COLOR. 1930-1933.

Type of Mating	Males					Females				
	Very Light	Light	Medium	Dark	Standard	Very Light	Light	Medium	Dark	Standard
Exhibition line			2	35	93			7	27	70
1. F_1—Exhibition males X Production females		3	37	15	15		14	27	10	1
2. F_1—Production males X Exhibition females		5	16	3			12	21	6	1
3. F_2 Generation		15	47	31	2	2	15	49	32	6
4. F_1 males X Production females		3	16	2			6	8	2	
5. Production males X F_1 females		35	28	1		5	44	33	8	
6. Exhibition males X F_1 females		2	11	13	10	2	6	9	15	5
7. Production males X F_2 females	2	10	6			1	17	11	1	
8. Exhibition males X F_2 females			1	6	6		2	4	6	9
9. Miscellaneous		3	19	24	6	1	19	28	42	20

The exhibition stock of both sexes was described as about 70 per cent standard in color with about 30 per cent dark or medium. The production stock showed no standard-colored birds, very few dark, with the great majority medium or light in color.

Reciprocal crosses to produce the F_1 generation gave significantly different results with respect to plumage color of male offspring but not of female offspring. Male offspring produced by mating exhibition males to production females were significantly darker in surface color than those from production males mated to exhibition females. In Table 2 the female offspring from the second type of mating showed a greater proportion of early maturing offspring than the first. It is probable also that the male progeny of this second type of mating were somewhat earlier maturing than those from the first type of mating. Since the lighter shades of red are more likely to occur in males than in females (Hays, 1932), it is probable that the males from the second type of mating were lighter because of physiological relations between sexual maturity and plumage color.

F_2 generation males on the average were slightly lighter in plumage color than either type of F_1 males. The segregation observed in this generation was not marked and this would indicate that neither parental type was homozygous for the factors affecting plumage color. This fact also accounts for the wide range in plumage color observed in the F_1 generation and renders difficult the establishment of uniform color by crossing exhibition and production birds. F_2 females showed about the same range in surface color as F_1 females.

In matings 4 and 5 the character of progeny from reciprocal crosses of F_1 hybrids on parental stocks is shown. Both sexes were lighter in color when the sire was of pure production ancestry. This fact suggests possible dominant sex-linked modifiers for lighter shades of plumage.

A comparison of progeny from matings 5 and 6, where production males and exhibition males were mated to F_1 females, indicates a dominant tendency of the light color carried by the production male. Here sex-linked relations do not stand out, however.

In progeny from matings 7 and 8, where production males and exhibition males were mated to F_2 females, the dominant nature of modifiers for light color is very evident. There again appear to be no sex-linked relationships.

Class 9 hybrids came from such matings as F_1 X F_2, F_1 and parental stock, and others. The plumage color of this progeny was essentially the same in both sexes and in general was similar to that obtained in the F_2 generation.

In general, these data on plumage color suggest dominance of light modifiers for color. The character of the progeny indicates further that color may be restored to the F_1 level by mating pure exhibition males on either F_1 or F_2 females. The general plumage color of F_1 hybrids is about intermediate between that of production-bred and exhibition-bred stocks.

Surface Color and Under Color

The under color of Rhode Island Reds should be of the same rich red color as the surface plumage. In breeding for color it is important to know whether different shades of surface color are associated with different shades of under color. Table 4 summarizes the combinations of surface and under color found in the exhibition stock and in the hybrid offspring from various types of mating.

The exhibition stock used in this experiment showed a rather intimate association between standard surface color and dark under color. In the males 74 per cent of those with standard surface color showed dark under color compared with about 79 per cent of the females. Of the total males, 70 per cent had standard surface color, and of the females 67 per cent.

In the class 1 progeny, 11 out of 15 standard-colored males also carried dark under color, and the single standard-colored female carried dark under color. A marked tendency is also observed for medium surface color to be associated with medium under color in both sexes. None of the light-colored males or females showed dark under color.

F_1 hybrids of class 2 were characteristically lighter in surface color than F_1 hybrids from the reciprocal class as noted in Table 3. There is here considerable association between surface and under color in both sexes.

If both sexes of F_2 hybrids are combined in studying under color, it will be observed that there were 30 light, 150 medium, and 68 dark, or a ratio of approximately 1-5-2. By combining the light and the medium classes, a 3 to 1 ratio appears. These facts suggest that under color may show a blending inheritance and that both the light and the dark phenotypes may be homozygous while the medium class is heterozygous for genes affecting under color. An examination of the F_1 progeny from exhibition males with dark under color mated to production hens with light under color showed essentially nothing but medium color, again suggesting a blending inheritance of under color. Several genes appear to be concerned in the inheritance of under color. An association between dark surface color and dark under color still appears in this generation.

From what has been said regarding the behavior of light and dark under color in crosses, the majority of class 4 progeny would be expected to be medium or

TABLE 4.--CLASSIFICATION OF EXHIBITION STOCK AND OF HYBRID OFFSPRING ACCORDING TO SURFACE COLOR AND UNDER COLOR

Under Color	Surface Color—Males					Surface Color—Females				
	Very Light	Light	Medium	Dark	Standard	Very Light	Light	Medium	Dark	Standard
	Exhibition Line									
Very light										
Light					3					1
Medium			1	18	21			5	9	14
Dark			1	17	69			2	18	55
	1. F₁ Progeny from Exhibition Males X Production Females									
Very light										
Light		1	2				5	5		
Medium		2	30	11	4		9	20	6	
Dark			5	4	11			2	4	1
	2. F₁ Progeny from Production Males X Exhibition Females									
Very light										
Light		2	1				10	5	1	
Medium		3	13	2			3	24	6	
Dark		1	5	2						1
	3. F₂ Hybrids									
Very light										
Light		4	1			3	13	7	2	
Medium		8	37	24	1		7	48	24	1
Dark		2	16	16	1			7	20	6
	4. Progeny of F₁ Males X Production Females									
Very light										
Light		1	1				6	5		
Medium		2	14	1						
Dark			1	1				3	2	
	5. Progeny of Production Males X F₁ Females									
Very light							2			
Light		17	4			8	43	11		
Medium		18	17				12	25	8	
Dark			7	1					1	
	6. Progeny of Exhibition Males X F₁ Females									
Very light										
Light			1			2	1	1		
Medium		1	14	13	9		5	7	9	5
Dark		1	3	10	12			2	10	2
	7. Progeny of Production Males X F₂ Females									
Very light										
Light		1	2				4	2		
Medium		2	9				3	4	2	
Dark			2	1						
	8. Progeny of Exhibition Males X F₂ Females									
Very light										
Light										
Medium				3	2	1	3	6	12	5
Dark			1	3	4			1	8	8

light in under color. Only those females that carried the gene for dark under color could produce progeny showing dark. Although the numbers are small, there is substantial agreement to expectation. Dark under color did not occur in birds classed as light in surface color.

Class 5 progeny were lighter in under color and also in surface color than class 4 progeny from the reciprocal cross. The data show very few individuals with dark under color, and none are classed as standard in surface color. Females from this particular cross tend to be lighter in under color than males.

In class 6 progeny, all birds with standard surface color carried either dark or medium under color. This group of birds showed decidedly darker surface and under color than the class 5 progeny. About 95 per cent of the birds from the exhibition males carried either medium or dark under color compared with about 51 per cent of those from the production males.

The number of birds concerned in class 7 is inadequate to furnish much information regarding surface and under color. The data suggest that males tend to be darker in under color than females when the dams carry dark color and the sires lack it.

The progeny of exhibition males X F_2 females were all medium or dark in under color. Surface color was also largely dark or standard. There is also some evidence that males showed darker under color than females. This fact would lend support to the idea that some sex-linked genes are concerned in under color.

In general, a study of the relation of surface and under color in various crosses of Rhode Island Reds indicates that dark surface and dark under color show considerable association. There is also evidence that light modifiers for under color are dominant to dark modifiers. Some evidence is also available which indicates sex-linked inheritance for at least part of the under color modifiers.

Surface Color and Smut

A smutty or slatey coloring in the feather fluff of Rhode Island Reds is an undersirable character. Nevertheless, breeders of exhibition birds find this character not at all uncommon and often use female breeding stock showing some smut for the purpose of improving surface color in the offspring. It is therefore important that consideration be given to the relation of smut and surface color in the various types of stock available. Table 5 presents a summary of the relation between surface color and smut in the exhibition stock and hybrid progeny.

Of the exhibition males of standard surface color, half carried smut in under color and half lacked smut. Of the females with standard color, only about one-fifth carried smut. These same proportions hold regardless of surface color, and suggest that smut is much more prevalent in the male sex.

Since none of the production birds used for crossing were of standard surface color and very few carried smut, there is opportunity to study the behavior of smut in crosses.

Of the F_1 offspring in class 1, males with either dark or standard surface color carried smut or were free from smut in almost equal numbers. Females with the same surface color showed about 36 per cent with smut. Of the 40 males classed as medium or light in surface color, about 32 per cent carried smut. Of the 41 females belonging to the medium or light classes, about 49 per cent showed smut. The F_1 generation as a whole was made up of 27 smutty males to 43 not smutty and of 24 smutty females to 28 not smutty. There was, therefore, a greater proportion of smutty individuals in the female progeny, suggesting that sex linkage may play a part in the transmission of smut.

The F_1 progeny in class 2 were distinctly lighter in surface color and freer from smut than the F_1 progeny from the reciprocal cross (class 1). Only 10 per cent of the male progeny from production males carried smut and 24 per cent of the females, while 39 per cent of the F_1 males and 46 per cent of the F_1 females

TABLE 5.--CLASSIFICATION OF EXHIBITION STOCK AND OF HYBRID OFFSPRING ACCORDING TO SURFACE COLOR AND SMUT

	Surface Color—Males					Surface Color—Females				
	Very Light	Light	Medium	Dark	Standard	Very Light	Light	Medium	Dark	Standard
Exhibition Line										
Smut			1	13	48			2	7	15
No Smut			1	22	45			5	20	55
1. F_1 Progeny from Exhibition Males X Production Females										
Smut		1	12	5	9		8	12	4	
No Smut		2	25	10	6		6	15	6	1
2. F_1 Progeny from Production Males X Exhibition Females										
Smut			3				1	8	2	1
No Smut		6	16	4			12	21	5	
3. F_2 Hybrids										
Smut		4	19	21	2	2	11	22	16	1
No Smut		10	35	19		1	9	40	30	
4. Progeny of F_1 Males X Production Females										
Smut			10	2			4	5	2	
No Smut		3	6				2	3		
5. Progeny of Production Males X F_1 Females										
Smut		5	7				23	13	3	
No Smut		30	21	1		8	34	23	6	
6. Progeny of Exhibition Males X F_1 Females										
Smut			8	16	13	2	6	4	4	2
No Smut		2	10	7	8			6	15	5
7. Progeny of Production Males X F_2 Females										
Smut		1	5	1			3	4	1	
No Smut		2	8				4	2	1	
8. Progeny of Exhibition Males X F_2 Females										
Smut				4	4		3	4	8	7
No Smut			1	2	2	1		3	12	6

from exhibition males showed smut. Smutty birds were confined almost exclusively to the group with medium or darker surface color.

In the F_2 generation there was something of a tendency for smut to segregate with light surface color, but the majority of males and females carrying smut were classed as having medium or darker surface color. In this second generation 42 per cent of the males and 39 per cent of the females showed smut. Thus the proportion of smutty birds in the second generation was about midway between that of the two classes of F_1 progeny.

The data for class 4 progeny are very limited but they suggest that smut is more likely to occur in birds with the darker shades of surface color.

When production males were mated to F_1 females (class 5), there was a tendency for smut to occur with the dominant lighter shades of surface color, especially in female progeny.

The same general situation with respect to smut and surface color was noted in the class 6 progeny from exhibition males and F_1 females; namely, that when smut occurred in birds with light surface color it appeared first in females.

The limited data presented for class 7 also give evidence that smut is more likely to appear with light surface color in females than in males.

The data for class 8 indicate greater freedom from smut in females than in males, also a greater tendency for smut to occur in females with the lighter shades of plumage color.

In general, the study of the exhibition stock showed that smut was more common in the male sex. When exhibition stock was crossed with production stock, observation of the progeny from eight different types of matings showed that, when smut appeared in birds with light surface color, it was more likely to be in the females. Possible sex-linked inheritance of smut is therefore suggested, but the tendency for the smut character to be more prevalent in the male sex regardless of surface color persisted in the different crosses. There was some evidence that smut is associated with dark surface color.

Under Color and Smut

Smut may be so extensive in the under color as to almost completely displace the normal red color. On the other hand, smut may be confined to a very narrow band in the feather fluff and may be observed only in certain body regions. Between these two extremes there are many gradations. As a rule, smut in under color is most likely to occur in the back; consequently all birds in these studies were carefully examined in the back region between the points of attachment of the wings. No attempt was made to record the different degrees of smuttiness. Under color was grouped into four shades of red. The relation between smut and under color in the exhibition stock and in the hybrid progeny is summarized in Table 6.

In the exhibition stock the under color was essentially the same for the smutty and the non-smutty groups of males. Among the females, however, there were more than three times as many non-smutty as smutty, and the great majority of non-smutty females showed dark under color. There is also some evidence in the females that smut in under color may lighten the shade of red pigment in the feather fluff.

In class 1 of the F_1 generation, medium and dark under color were more prevalent in non-smutty individuals in both sexes. There was still a greater proportion of females than males with dark under color and no smut. Furthermore there was evidence of blending in shade of under color in both sexes.

The greater percentage of non-smutty progeny in class 2, when production males were used, suggests sex-linked relations for the transmission of smut. The fact that all males showing dark under color were free from smut indicates that smut is not a necessary accompaniment of dark red under color.

The F_2 offspring of both sexes averaged intermediate in under color, while 42 per cent of the males and 38 per cent of the females showed smut. The original exhibition stock showed 48 per cent of males with smut and 23 per cent of females. The combined F_1 generation gave 30 per cent of the males and 36 per cent of the females with smut. The gross data suggest that smut segregated as a dominant in the F_2 generation. Dark under color was prevalent in F_2 birds of both sexes that were free from smut.

The limited data for class 4 indicate that smut is rather commonly associated with light under color in females. In the male progeny this relation does not hold, in these hybrids at least.

Progeny from the back cross, class 5, are rather similar to those in class 4. The data do not indicate, however, that light under color and smut are more common in the female offspring. Only 19 per cent of the males were smutty compared with 35 per cent of the females. Under color was also somewhat lighter in the females.

In the class 6 back-cross population, the greater proportion of both males and females with dark under color were free from smut. Smut was more prevalent in birds with medium or light under color. As a whole, 58 per cent of the males and 41 per cent of the females were smutty. Under color was darker than that of the class 5 progeny of production males mated to F_1 females.

The back-cross progeny from production males, class 7, were about 50 per cent smutty in each sex. The data are inadequate to bring out any relation between smut and under color.

The class 8 progeny from back crossing F_2 females with exhibition males gave only medium and dark under color. These progeny were essentially the same in under color as the exhibition stock; but the females were equally divided into smut and non-smut classes, while exhibition females were very low in smut.

The general results of the study of the relation of under color and smut in these hybrid offspring showed some evidence that sex-linked dominant genes are concerned in the transmission of smut, that smut in under color may lighten the shade of red pigment in the feather fluff, and that lighter shades of under color appear to be governed by dominant genes.

TABLE 6.--CLASSIFICATION OF EXHIBITION STOCK AND OF HYBRID OFFSPRING ACCORDING TO UNDER COLOR AND SMUT

	Under Color—Males				Under Color—Females			
	Very Light	Light	Medium	Dark	Very Light	Light	Medium	Dark
Exhibition Line								
Smut		2	21	39			12	12
No Smut		1	19	48		1	16	63
1. F_1 Progeny from Exhibition Males X Production Females								
Smut			21	6		8	16	1
No Smut		3	26	14		2	19	6
2. F_1 Progeny from Production Males X Exhibition Females								
Smut			3			2	9	1
No Smut		3	15	8		14	24	
3. F_2 Hybrids								
Smut		2	31	13		13	31	8
No Smut		3	39	22		12	49	25
4. Progeny of F_1 Males X Production Females								
Smut			11	1		7	4	
No Smut		2	6	1		4	1	
5. Progeny of Production Males X F_1 Females								
Smut		2	9	1	1	14	24	
No Smut		19	26	7	1	48	21	1
6. Progeny of Exhibition Males X F_1 Females								
Smut			28	9		3	10	5
No Smut		1	9	17		1	16	9
7. Progeny of Production Males X F_2 Females								
Smut			5	2		4	4	
No Smut		3	6	1		2	5	
8. Progeny of Exhibition Males X F_2 Females								
Smut			5	3			14	8
No Smut				5			13	9

GENERAL SUMMARY

Exhibition stock and production stock and their hybrid offspring were compared in fecundity characters, characters related to fecundity, and egg production; also in plumage color, shade of under color, and the occurrence of smut.

Compared with the production-bred stock, the exhibition stock used were characteristically late maturing, low in intensity, good in egg weight, low in hatchability, low in broodiness, low in persistency, low in mortality, and low in egg production.

In surface plumage color the exhibition stock showed about 70 per cent meeting standard requirements and about 30 per cent classed as dark or medium in color. The production stock had no standard-colored birds, very few dark red, and the majority were either medium or light red in color. Practically all exhibition birds ranked as dark or medium in under color, while all production stock ranked as light or medium. Half of the exhibition males and about one-fifth of the females carried smut in under color. Very few production birds showed smut.

The study of the hybrid offspring obtained from the various matings yielded the following conclusions:

1. Crossing the two lines gave somewhat diverse results with respect to fecundity traits in reciprocal crosses. When the production stock was used for the male parent. the progeny were superior to those from the reciprocal cross, and such F_1 hybrids gave slightly greater egg production during the year.

2. Segregation in the F_2 generation gave a high percentage of late-maturing birds, more low-intensity birds, more individuals with winter pause, more broody birds, decreased persistency, and increased mortality. Egg production was decidedly lower than in the checks.

3. Back crossing either F_1 or F_2 females with production males raised the egg production to near the level of production-bred birds.

4. In surface plumage color the F_1 generation was essentially intermediate between standard and production color, but the hybrids from exhibition mothers were decidedly darker in color than those from the reciprocal cross.

5. Lighter shades of surface color appear to dominate the darker shades.

6. The surface color may be restored to the F_1 medium color by back crossing either F_1 or F_2 females on exhibition males. The development of a line of birds with standard surface color from such crosses would be exceedingly difficult.

7. Dark surface and dark under color were rather intimately associated. Light modifiers for under color seemed to dominate, and there was some evidence of sex-linked modifiers.

8. Smut was more common in the male sex. Smut in the females was most likely to be associated with the lighter shades of surface color. There was some evidence that smut tends to be associated with dark surface color in males.

9. The inheritance of smut depends in part upon sex-linked dominant genes.

10. Smut tends to lighten the shade of red pigment in feather fluff.

11. Lighter shades of red in under color appear to be governed by dominant genes.

12. By crossing light-colored production-bred Rhode Island Reds with exhibition-bred birds, followed by careful matings, a flock may be built up with rather uniform medium red plumage color and high egg production.

REFERENCES

Hays, F. A., and Ruby Sanborn. 1924. The inheritance of fertility and hatchability in poultry. Mass. Agr. Expt. Sta. Tech. Bul. 6.

Hays, F. A. 1932. The relation of feather pigmentation to intensity of laying in Rhode Island Reds. Mass. Agr. Expt. Sta. Bul. 288.

Hays, F. A. 1933. Crossing production and exhibition Rhode Island Reds. Amer. Nat. 67: 539-548.

Warren, D. C., and C. D. Gordon. 1933. Plumage and eye color inheritance in the single comb Rhode Island Red fowl. Jour. Agr. Research 47:897-910.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 317

February, 1935
Revised May, 1936

Blueberry Culture in Massachusetts

By John S. Bailey and Henry J. Franklin

Although the wild blueberry is native to New England, there was little interest in its improvement until cultivated varieties attracted attention. Since then, there has been a demand for information on varieties and cultural methods which this bulletin aims to supply.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

BLUEBERRY CULTURE IN MASSACHUSETTS

By John S. Bailey[1], Assistant Research Professor of Pomology, and Henry J. Franklin, Research Professor in Charge of the Cranberry Station at East Wareham

Blueberries, although not peculiar to the New England States, grow wild here in great profusion. Massachusetts has received her share of this gift from the hand of Mother Nature.

But man, being hard to please, was not satisfied with Nature's gift. He wanted sweeter and larger berries. To satisfy this desire Dr. F. V. Coville of the United States Department of Agriculture started his pioneering experiments on culture and breeding of blueberries, which laid the foundation for their commercial production. His breeding work produced several named varieties with fruit larger and more handsome than that of wild bushes. These varieties were developed from the highbush or swamp blueberry, *Vaccinium corymbosum* L., and therefore have the growth habit and soil and climatic requirements of that species. Dr. Coville received valuable assistance from Miss Elizabeth C. White of New Lisbon, New Jersey, who provided much of the foundation stock for his breeding work and was a pioneer in developing production on a commercial scale.

Although relatively few acres of these named varieties of blueberries have been planted in Massachusetts, there is a growing interest in their culture which has led to an increased demand for information about them. This bulletin is meant to serve as a guide to those interested in blueberry growing. To make it more serviceable a section is included which contains suggestions for the more profitable management of wild blueberry lands.

Soil Requirements

The fact that the highbush blueberry commonly grows in low, swampy places has led many people to the erroneous conclusion that this species of blueberry will do best under such conditions. Blueberries grow in low, swampy places because they tolerate such conditions better than many other plants and hence have less other vegetation to compete with than on more fertile soils. But removed from the competition of other vegetation, the swamp blueberry thrives much better on a fertile soil than on a poor one.

The ideal blueberry soil is fertile, has a plentiful and continuous water supply, is well drained and aerated, is well supplied with organic matter, and is acid.

Since success with cultivated blueberries depends on growing large berries, it is essential that the plants be kept in a highly vigorous condition. Because of the severe pruning required, as will be explained later, the necessity for vigorous growth cannot be overemphasized. A fertile soil is therefore important.

---

[1] The authors wish to thank Mr. J. L. Kelley of the United States Department of Agriculture for helpful criticisms and suggestions, particularly in regard to the section on propagation, and also Mr. F. E. Cole of the Worcester County Extension Service for supplying the information for the section on the improvement of wild highbush blueberries. This information was obtained from experiments started by Mr. Herbert Reiner, formerly with the Worcester County Extension Service.

An adequate and continuous water supply is one of the essentials of a good blueberry soil. A soil which dries out, even for short periods, during the summer can never be made suitable for blueberry growing unless some method of supplying water is provided. However, the roots should not be standing in water. Too much water is worse than too little. From the first of November to the first of April blueberries will tolerate standing water, but during the growing season an excess of water is very likely to be fatal. The two plants on the right in Fig. 1 received an excess of water and four days later had dropped most of their leaves. These plants later died. Since the blueberry should have neither too much nor too little water and since it is a shallow-rooted plant, the ideal blueberry soil has a water table 14 to 22 inches below the surface. This provides an adequate and continuous water supply without in any way interfering with the growth of the plants. If the water table is higher than 14 inches, the land should be drained before blueberries are planted.

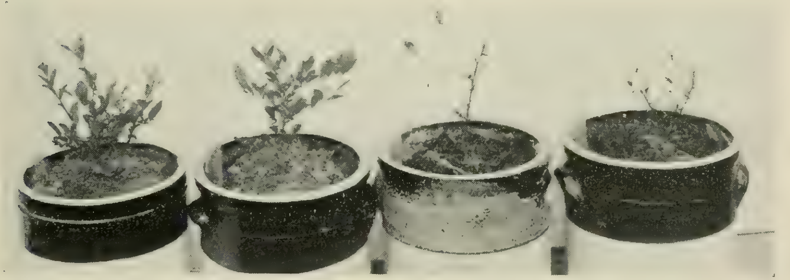


Figure 1. Water Injury.
The two plants on the left are normal plants; the two on the right had the soil saturated with water.

It is not known how essential organic matter may be under all soil conditions. With very light sandy soils it seems to be essential, but on heavier, more fertile soils it may not be so necessary. However, experimentation and observation indicate that the plants grow much better if the soil contains a liberal amount of organic matter.

Blueberries, to attain their greatest development, require an open, well-aerated soil. Bushes which grow in swampy places are situated on hummocks of land where their roots are out of water and therefore well aerated during the growing season. Even where moisture conditions are favorable, blueberries thrive much better in a well-aerated soil.

The blueberry requires an acid soil but just how acid is uncertain. Although a soil reaction of pH 4.5 — 5 is supposed to be best for blueberries, an examination of the soil in thirty plantings showed a pH range of 4.3 to 5.9. The variation in growth on these different soils was much more closely correlated with one or more of the other soil factors mentioned above than with soil acidity. Most of the soils of Massachusetts are strongly acid (pH 4 — 5.5) unless they have been limed. Some small areas of limestone origin in Berkshire County have surface soils which, without the application of lime, are only slightly acid and subsoils which are even less acid or neutral.

There is much land in the State suitable for blueberry growing. The presence of wild swamp blueberry, leatherleaf, cranberry, white cedar, or red maple indicates a favorable soil. There are probably many abandoned cranberry bogs in the southeastern part of the State that could be made into satisfactory blueberry fields. Low meadows are often suitable provided there is adequate air and water drainage. Hillsides also may be used if the soil conditions are right. Soils previously used for growing garden crops are usually unfit for blueberries because they have been limed and are too nearly neutral. Such soil may be made suitable by thoroughly mixing with it a large quantity (at least 1 bushel per plant) of woodland turf, fallen leaves, or peat.

Preparation of Land

If the land has not been under cultivation, it must be cleared of all trees, stumps, and bushes. If it is low and wet, it needs to be drained so that the water table will be at least 14 inches below the surface at all times. Any low spots in the field should be filled in or drained so that there will be no standing water at any time during the growing season.

After the field has been cleared and drained, it should be plowed deeply enough to thoroughly mix the turf with the underlying soil, and disc harrowed to pulverize and mix the soil well. The soil thus prepared may be allowed to stand fallow for a year or used for a cultivated crop. This is much more important if a sod that might harbor white grubs has been plowed in, because the grubs are very apt to injure the roots of the small plants after they are set. An occasional discing while the land is lying fallow will put it in much better condition and add to the chances of success with the plants.

Selection of Varieties

Although the blueberry is a new-comer among cultivated fruits, several desirable varieties are already available. The ideal variety has a vigorous and productive bush able to produce a heavy crop annually and at the same time make abundant wood growth. An upright habit of growth is desirable to make picking easy and to keep the berries from getting dirty. The bush must be easy to prune, disease resistant, especially to the disease called mummy berry, and hardy at low winter temperatures.

The berries of the ideal variety are large and uniform in size, which they maintain throughout the season. Blue color, an abundance of bloom over the surface, and pleasing flavor are desirable; good keeping and shipping quality are essential. The sepals, which remain adhering to the fruit, are small and closely appressed to the skin. The skin is as thin and tender as possible without sacrificing shipping quality. The berries hang to the bushes well but separate from the stem readily enough to prevent tearing of the skin.

The three varieties recommended for commercial planting are, in order of ripening, Cabot, Pioneer, and Rubel.

Cabot is an early variety, ripening from the first to the middle of July. The berries are large in size, excellent in quality, and good shippers. The plants are low and spreading and not as vigorous as Pioneer and Rubel. They are hard to propagate and prune and are very susceptible to crown gall. Cabot will probably be less profitable in Massachusetts than the later varieties, because it is likely to suffer in the market from competition with cultivated berries shipped from the South.

PIONEER is an excellent commercial variety ripening a week to ten days after Cabot. It produces large crops of berries which are superior in appearance, flavor, and keeping quality. The bush is medium in height and of fine appearance for ornamental planting. It is more costly to prune than many of the other varieties.

RUBEL is a late variety ripening a few days after Pioneer. It is a good producer. The berries are only fair in size, but their quality is good and they ship well. The bush is tall, upright, well shaped, vigorous, and easy to propagate and prune. Because of less competition from the South, this will probably be the most profitable of the commercial varieties in this State.

The following varieties are recommended for trial:

CONCORD is a mid-season variety. The vigor of the bush is good but the yield is only fair. The berries are very large, handsome, and excellent in quality. They hang on the bush better than those of most varieties. This may lead to delayed picking and result in reduced keeping quality.

RANCOCAS ~~ripens with Rubel~~. The bush is upright, and fairly vigorous and productive. The berries are good in quality but tend to run small the latter part of the season and do not keep well. It is more costly to prune than some of the other varieties. Ripens a few days after Cabot.

WAREHAM ripens somewhat later than Rubel. The bush is a vigorous grower, but tends to grow so late that it is susceptible to winter injury. It requires less pruning than some varieties and yields heavily. The berries are of good size throughout the season and keep fairly well but, because of their dark color, are not as fine in appearance as the fruit of some other varieties.

JERSEY ripens a few days after Rubel. The bush is very vigorous and productive but does not sprout from the base as freely as is desirable. The berries have good color, size, and keeping quality. The stems are long, which makes the cluster so open that the berries are easily picked. The calyx lobes protrude, detracting somewhat from the appearance of the berries.

Propagation

The propagation of highbush blueberries depends mostly on the proper control of five factors: aeration of the propagating medium, moisture in the propagating medium, humidity in the propagating frame, light, and temperature. The first three of these factors are so closely associated that practically they are controlled together.

Lack of aeration in the propagating medium, because it is too compact or too wet, will cause the cuttings to rot at the base and die. Aeration will be sufficient if there is drainage below the propagating bed to allow excess water to drain off and if ventilation is given over the bed. Under these conditions the moisture in the propagating medium can be kept high enough to keep the cuttings from drying out and to maintain humidity over the bed without interfering with aeration. The bed can be watered heavily when necessary, for most of the excess water will drain off through the bottom and ventilation will take care of the rest.

It is important to maintain humidity over the propagating bed because of the nature of the rooting process in blueberry cuttings. They make a top growth before they develop roots; therefore, the air above the bed must be kept moist enough to prevent this succulent new growth from wilting. Humidity can be maintained by using glass sash over the beds; but unless constant attention is paid to ventilation, the propagating medium may become water-logged and the cuttings die from lack of aeration.

As soon as the cuttings have made a top growth and produced leaves, they begin to manufacture food for themselves if they have light enough. Therefore, the cuttings should be given all the light they will stand by removing the shades on cloudy days. However, the shades must be put back on the propagating beds immediately if the sun comes out, because even a few minutes of bright sun on the cuttings often kills them.

The only temperature control necessary is to keep the propagating beds from becoming too hot. This is accomplished by shading and ventilation.

The time to take blueberry cuttings is in the spring before growth starts. It is a common practice to prune the bushes in late March and then cut from the prunings the wood suitable for propagating purposes. Great care is necessary to prevent this material from drying out.

The cuttings are made from wood of the previous season's growth and must contain no fruit buds. Weak, spindling cuttings are not desirable because plants grown from them are usually small, weak, and slow in growth. On the other hand, cuttings over one-fourth inch in diameter seem to root less readily than the smaller ones: but when they do root, they usually make larger, more vigorous plants. The best length is three to four inches, with the top cut made just above a bud and the bottom cut just below and as close to a bud as it can be made without injury to the bud. All cuts should be slanting and made with a very sharp knife in order that they may be clean and smooth.

The best propagating medium consists of a mixture of about 75 percent peat and 25 percent sand. Because of the variation in American peats, unless one known to be a good propagating medium can be obtained, it is better to use German peat of the grade GPM. An ordinary cold frame makes a satisfactory propagating frame if there is good drainage below it. About six inches of the propagating medium is necessary and should be packed down well and leveled. To prevent injury by root grubs, wire screen may be placed in the bottom of the bed. German peat must be wet before use. This material is very difficult to wet with cold water but can be wet easily with hot water.

The best time to set the cuttings is about April 1 or before the buds begin to break. It is best to start with the earliest varieties. They can be put in the medium either at an angle of 45° or vertically, one inch apart, in rows two inches apart. If each cutting is placed deeply enough in the medium so that only the top bud remains above the surface, usually only this bud will develop and a better plant will be formed.

After the cuttings have been placed, the bed should be watered thoroughly and the sash put in place. The shades can be left off until the buds begin to break. This is desirable if the weather is cool. The shades may be made either of burlap or slats supported about four inches above the sash. If the shades are made of slats, the proportion of slats to space ought to be about three to one. During the rooting period the cuttings must be watched closely. If any show signs of rotting, the frames need to be ventilated by raising the sash slightly. The shades are removed on cloudy days but must be replaced immediately if the sun comes out.

When the cuttings have started to root, the latter part of June, ventilation of the frames is started and is gradually increased until the sash can be removed. The latter part of August, the amount of light given the cuttings can be gradually increased by taking off the shades earlier in the evening and replacing them later in the morning, until they can be left off altogether.

The young plants may be left in the cold frame during the winter with some hay, straw, or similar material placed over them for protection. In the spring they are set in a nursery where they are grown for one or two years before they are ready to put in the field. The nursery should be kept well cultivated, but the cultivation must be shallow so as not to disturb the roots of the plants.

Planting

Planting should be done as early in the spring as the condition of the soil permits. The plants are set five feet apart, in rows eight feet apart. So spaced 1,089 plants per acre are required. Each plant as received from the nursery has the roots covered by a ball of earth which should be disturbed as little as possible in planting. When the plants are set, the holes are dug large enough for the roots to be placed without crowding and deep enough so that about one inch of the stem will be below the surface of the soil. Under some conditions blueberry varieties may be self-sterile, or nearly so. Therefore, it seems best to plant at least two varieties . They can be set in alternate rows if they are equally desirable, but if not, at least every fourth row should be a different variety.

Soil Management

Blueberry plantings are usually kept under cultivation, which is started as early in the spring as the soil can be worked and stopped about the middle of August. Continued later than this it may cause late growth and make the plants susceptible to winter injury.

Since blueberries are shallow rooted, cultivation should not be deep, particularly close to the plants. In recent experiments in New Jersey (2) cultivation two to four inches deep between the rows gave better results than cultivation one to two inches deep. They, therefore, recommend cultivation to an average depth of three inches between the rows but no nearer to the plants than the ends of the branches. To keep down weed growth close to the plants, they recommend hand hoeing or very shallow cultivation with an acme harrow. This agrees with experience in Massachusetts that some cultivation is necessary to keep the soil from becoming hard and poorly aerated but that deep cultivation close to the plants does more harm than good.

Fertilization

The blueberry, like most plants, responds to fertilization. Nitrogen generally has the most effect on both growth and yield, but recent experiments in New Jersey (2) indicate that a complete fertilizer is desirable because nitrogen used alone causes an excessive shoot growth.

Young blueberry plants are easily injured by too much fertilizer. No fertilizer need be applied the year the plants are set. The first year after planting, a small handful well spread out around each plant is enough. The next year a little more may be used. If the fertilizer is mixed with about three times its weight of dry sand before being applied, it is less likely to cause injury.

The third year and thereafter the fertilizer can be broadcast between the rows and the amount gradually increased until five to six hundred pounds to the acre are used when the bushes begin to bear. This heavy fertilization of the bearing bushes is recommended because long, vigorous shoots are necessary for the production of the largest and best berries and because very vigorous growth is needed to replace the large amount of wood removed in pruning.

The following mixture is recommended:

Nitrate of soda	640 pounds
Concentrated tankage	640 pounds
Superphosphate	300 pounds
Sulfate of potash	420 pounds

This mixture should be applied in the spring when the bushes start to grow. A thorough cultivation after the fertilizer has been applied is beneficial.

Pruning

Pruning is one of the most important operations in the growing of blueberries. The purpose of pruning is to produce as many good vigorous shoots as possible in the top of the bush, to keep vigorous new shoots growing from the base of the plant, to prevent the bush from overbearing, and to stimulate the production of large berries. It must be done in the winter or early spring before growth starts.

The bushes need little or no pruning the first two years in the plantation. Only the short, weak branches need be removed. The bushes should not be allowed to bear during this period because this will greatly reduce growth and delay the production of a commercial crop. Therefore the fruit buds are removed during the pruning operations. If any are missed, the flowers may be pruned off when the bushes come into bloom.

To prune bearing bushes correctly, one must know their bearing habit. The fruit buds are produced on the terminal portion of the shoots. They are formed in the axils of leaves during the summer, remain dormant during the winter, then bloom and produce fruit the following summer. Fig. 3 shows at (a) the terminals with their fruit buds. Fig. 5 shows shoots with their fruit buds (a) and leaf buds (b).

The pruning treatments given to the different varieties vary according to the character of their growth. Varieties producing many shoots from the base require more thinning out of this growth than those which grow few such shoots. Varieties which branch freely need more thinning out in the top than those which do not. Varieties with fruit buds on the terminal two-thirds or three-fourths of the shoots require more cutting back than those with fruit buds on only the terminal third or fourth of the shoots. Therefore, the following outline of pruning practice is given as a general guide and not as a set of rules.

First, remove or cut back a few of the older branches such as (b) in Fig 3. These branches when they are three or four years old tend to produce many short, weak shoots which yield small berries.

Second, remove all branches which are so near the ground that the fruit would get dirty.

Third, remove the shorter, weaker shoots to prevent crowding of the branches.

Fourth, cut back shoots with too many fruit buds. Three or four such buds

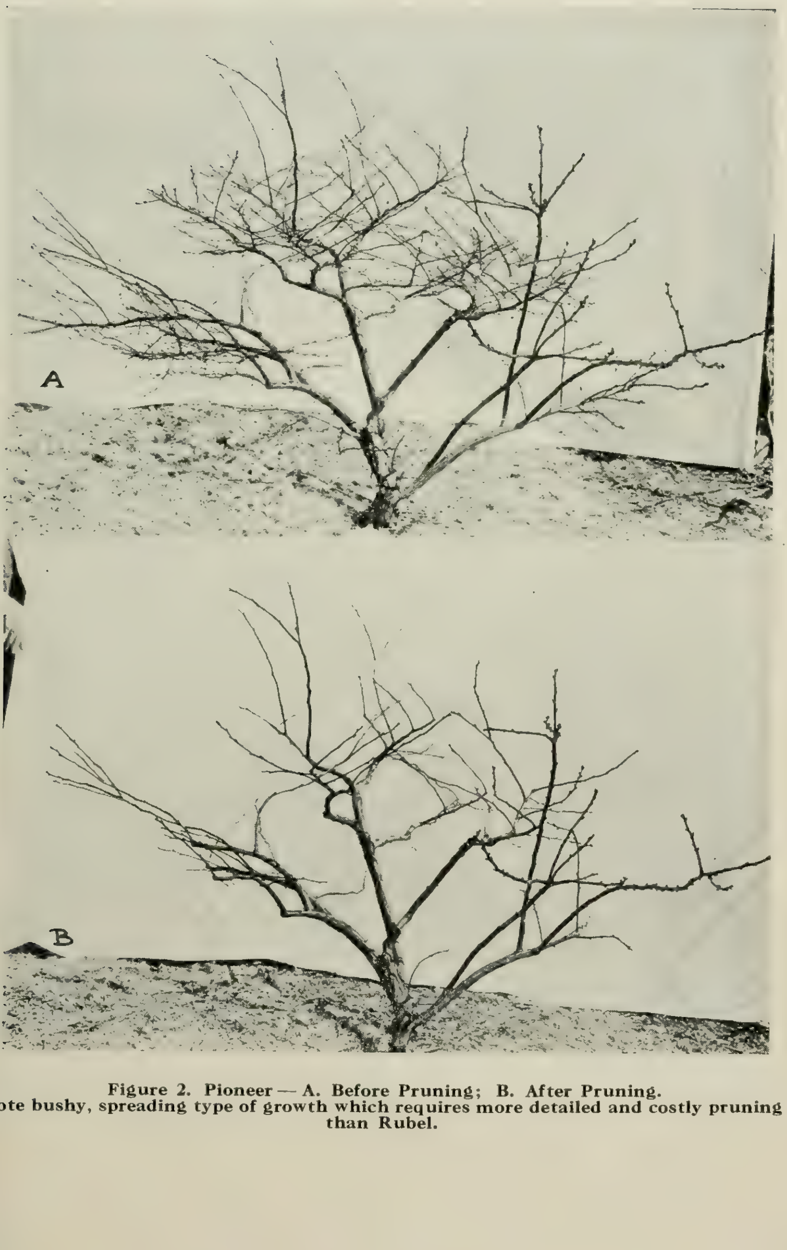


Figure 2. Pioneer — A. Before Pruning; B. After Pruning.
Note bushy, spreading type of growth which requires more detailed and costly pruning than Rubel.

are enough on a shoot because each bud produces a cluster of eight or ten berries and if more buds are left, so many berries will develop that they will be small. Some varieties, such as Cabot, grow many fruit buds in proportion to the number of leaf buds and must be cut back one-half to two-thirds of their length. In Fig. 5 the three shoots on the right illustrate such a condition. Other varieties, such as Rubel, produce relatively few fruit buds in proportion to the number of leaf buds and need little or no cutting back. This condition is illustrated by the three shoots on the left in Fig. 5.

Finally, study the plants to learn their needs. Cut heavily to encourage new growth. If you are pruning for the first time, get expert advice if possible.

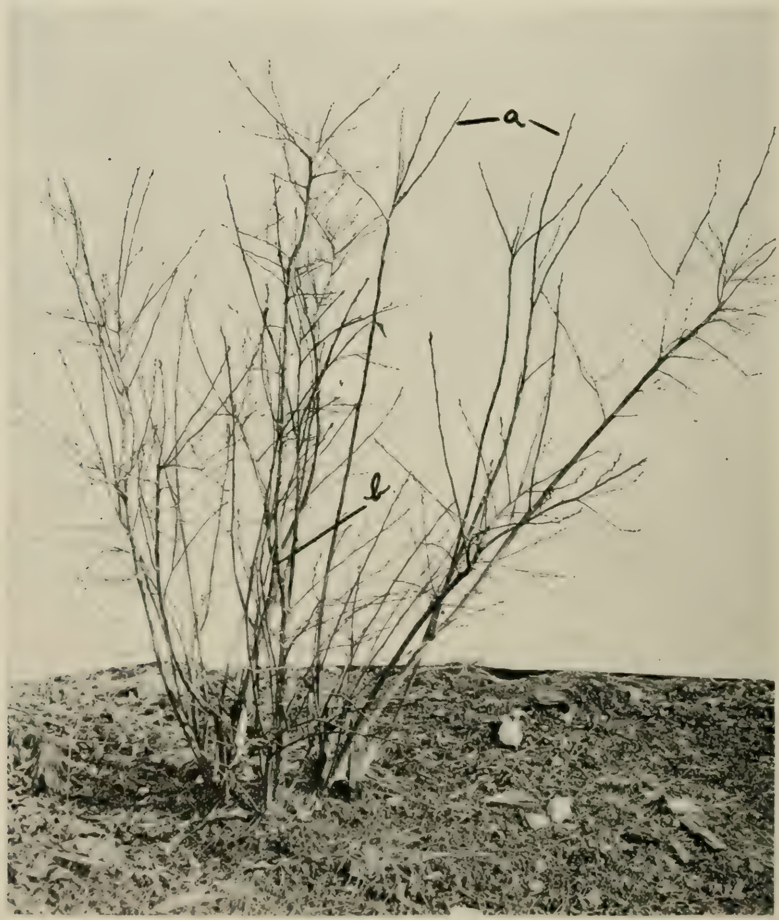


Figure 3. Rubel — Before Pruning.
(a) Terminal shoots with fruit buds; (b) old branch to be cut out.

Insects and Diseases

The cranberry fruit worm, *Mineola vaccinii* Riley (5) sometimes attacks blueberries. The mature worm is about one-half inch long. It has a yellowish head and a green body often tinged with red on the back. Several berries are often webbed together and the worm works among them. No control has been found for this insect but it has not yet become a serious blueberry pest.

The cranberry weevil, *Anthonomus musculus* Say, is sometimes a serious blueberry pest. The adult is a long-snouted beetle similar to the plum and apple curculios but smaller. The larva is a legless whitish grub with a yellow head and is about one-ninth of an inch long. Some injury is done to the flowers by the feeding of the adults, but most of the injury is done by the larva feeding on the fruit and tender young foliage. This insect can be controlled by spraying

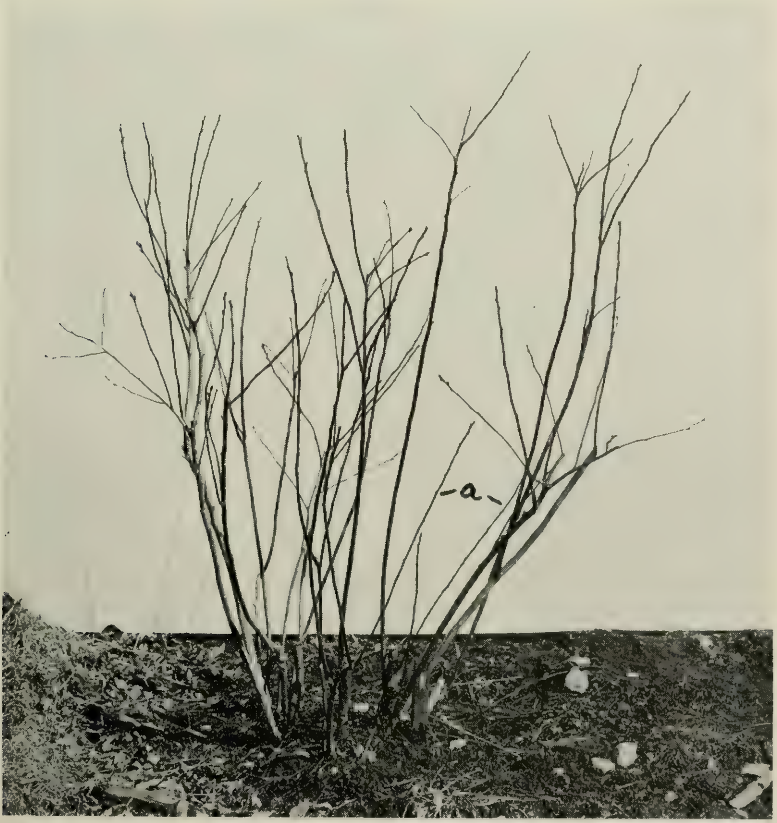


Figure 4. Rubel — After Pruning.
(a) Desirable new shoots growing from the base of the plant.

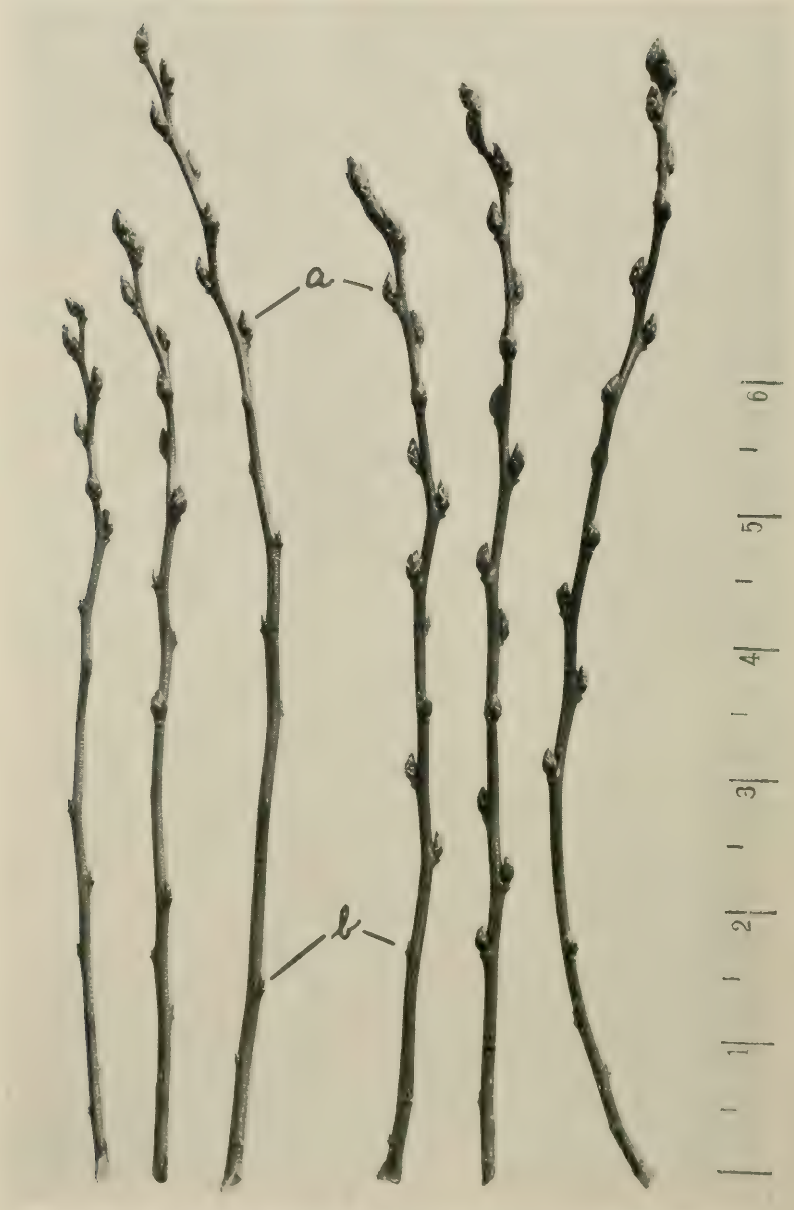


Figure 5. Terminal Shoots Showing Difference in Bearing Habit. Note difference in proportion of fruit buds (a) to leaf buds (b).

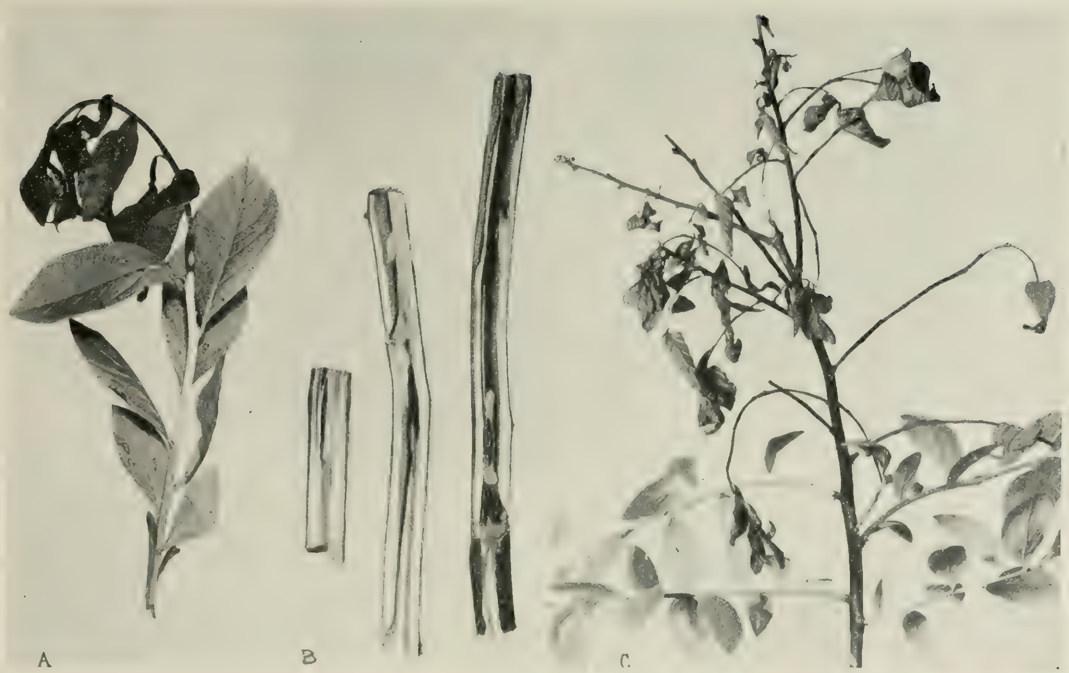


Figure 6. Blueberry Stem Borer.
A, Dead tip resulting from egg laying girdles; B, larva in tunnel; C, dead tip of branch due to boring of larva.

in the spring after growth starts but before egg laying begins, usually about May 20, with Bordeaux mixture and calcium arsenate made up as follows:

Stone lime	10 pounds
Copper sulfate	6 pounds
Water	100 gallons
Calcium arsenate	6 pounds
Fish-oil soap	4 pounds

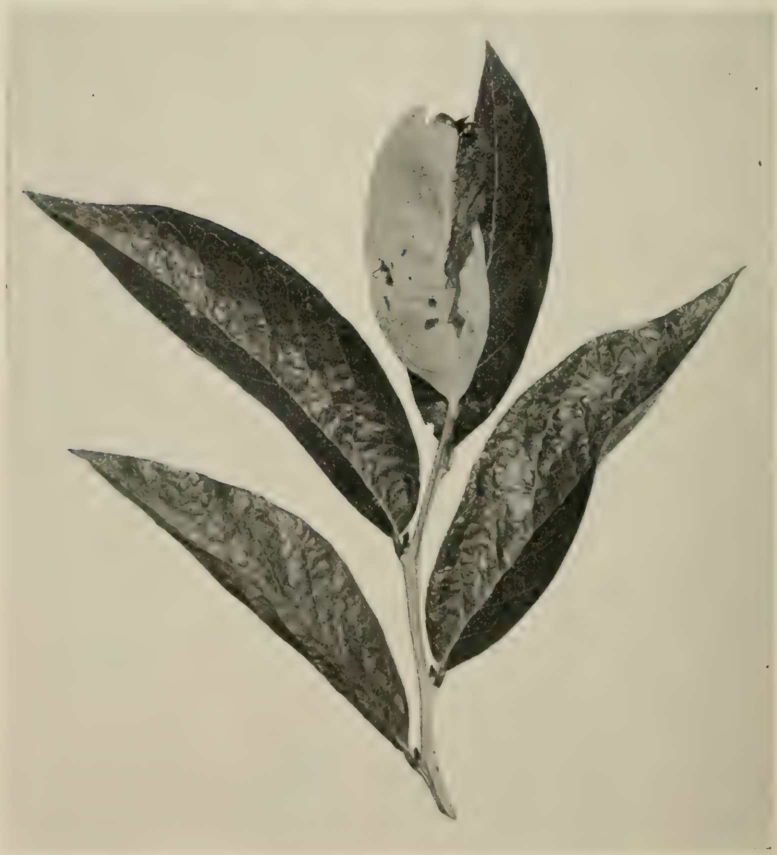


Figure 7. Red-striped Fireworm Injury on Blueberry.

The blueberry stem borer, *Oberea myops* Hald., (4) sometimes does considerable damage to blueberry bushes. There are two kinds of injury caused by this insect: injury to the young shoots by the adult beetles during egg laying (Fig. 6A); and injury to older stems and sometimes to the roots by the feeding of the larvae (Fig. 6B and C.)

The beetles lay their eggs in the young shoots about six inches from the tip.

A shoot is girdled in two places about one-half inch apart and an egg is deposited in a slit in the bark between these girdles. The tip of the shoot is killed by the girdling, turns brown, and often breaks off at the top girdle.

When the egg hatches, the young larva bores down the center of the shoot. This it continues to do for two or three years and may even get down into the roots. The infested stem usually dies. If the borer gets into the roots, it weakens the whole plant causing the leaves to turn a yellowish or reddish color.

This insect can be largely controlled by breaking or cutting off the dead tips during the summer. Pickers can do this during the picking operations. If the egg has hatched and the larva has started to bore, the shoot should be cut off below the lower end of the tunnel. Infested stems missed during the summer will usually be found during the pruning operations the following winter and can be removed then. Since the larva is a legless grub and cannot crawl back to the bush, the infested shoots may be dropped on the ground. If borers have gotten into the roots, a piece of baling wire shoved down the tunnels will kill most of them.

The red-striped fireworm, *Gelechia trialbamaculella* Cham., does some damage to blueberries at times. The larvae, which are pale green when small, develop reddish brown stripes along the back and sides as they grow older until they appear to have a solid color unless closely examined. These worms fasten two or more leaves together and feed between them (Fig. 7). They make a tubular case of silk covered with brown castings. The injury to older leaves is slight, but the stunting of succulent new shoots due to the work of these worms on the terminal leaves is more harmful. A thorough application about August 6 of the following spray will control this pest very effectively:

40 per cent Nicotine Sulfate	1 quart
Fish-oil Soap	4–5 pounds
Water	100 gallons

White grubs, *Phyllophaga* sp., may cause injury to the newly set plants, especially in meadowlands. This injury may be greatly reduced by keeping the land fallow or growing a cultivated crop for a year before the blueberries are set.

The caterpillars of the gipsy moth, *Porthetria dispar* L., sometimes do considerable damage but they are easily checked by spraying with lead arsenate — 6 pounds of dry arsenate to 100 gallons of water applied about May 20.

Red-humped apple caterpillars, *Schizura concinna* Smith and Abbot, sometimes feed on the blueberry. Since they feed in colonies, they can strip a branch of leaves in a short time. They appear in August or September. If only a few are present, they can be shaken from the bush and crushed. If they are abundant, spray with lead arsenate, 4–5 pounds to 100 gallons of water.

The cranberry spittle insect, *Clastoptera saint-cyri* var. *saint-cyri* Prov., infests blueberries occasionally. It is a sucking insect about one-eighth of an inch long, appears usually in early June, and is conspicuous because of the mass of froth with which it covers itself. It can be controlled by spraying with:

Nicotine Sulfate	1⅓ quarts
Fish-oil Soap	4 pounds
Water	100 gallons

Mummy berry is the most common disease of cultivated blueberries. It is caused by a species of Sclerotinia which rots and mummifies the green or partly ripe fruit rather badly in some years. In the late summer the dry, shriveled, gray, mummied berries (Fig. 8) may be found on the ground under infected bushes. Sanitary measures, such as removing wild bushes around the planting and brushing the mummied berries into the middle of the spaces between the rows and covering them by cultivation, will reduce the damage from this disease.

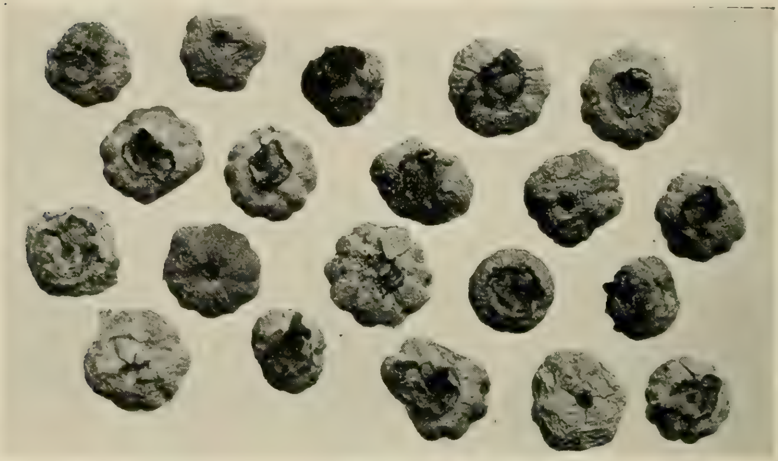


Figure 8. Mummy Berry Disease, Caused by a Species of Sclerotinia.

The cranberry Phomopsis usually causes the rather sudden death of more or less canes during the summer. Affected canes should be cut out promptly and burned.

Crown gall, a bacterial disease caused by *Bacterium tumefaciens*, infects cultivated blueberries as well as apple, pear, peach, plum, quince, raspberry, and many other plants. On the blueberry it usually appears as knotty swellings on the stem or branches (Fig. 9), but may appear as nodules on the roots. It is spread by the use of infected propagating wood and possibly on pruning tools. It may live over in the soil or in dried-up galls in the soil. The variety Cabot is very susceptible to crown gall, which has been found also on Pioneer, Concord, Rubel, and Rancocas. Since this is primarily a nursery disease, it need give the grower little concern provided he gets clean plants. The only method of control is to remove and burn infected bushes at once.

Witches broom, which gets its name from the type of growth it induces (Fig. 10), is caused by the fungus *Calyptospora columnaris*, one of the rust fungi. It is perennial on both highbush and lowbush blueberries. It does not spread from blueberry to blueberry but must pass through an alternate host, the balsam fir, from which it spreads to the blueberry. Fortunately this is not a serious disease, for no control has been found. The spread of the disease in an infected plant can be stopped by cutting off the diseased branch several inches below the affected part.

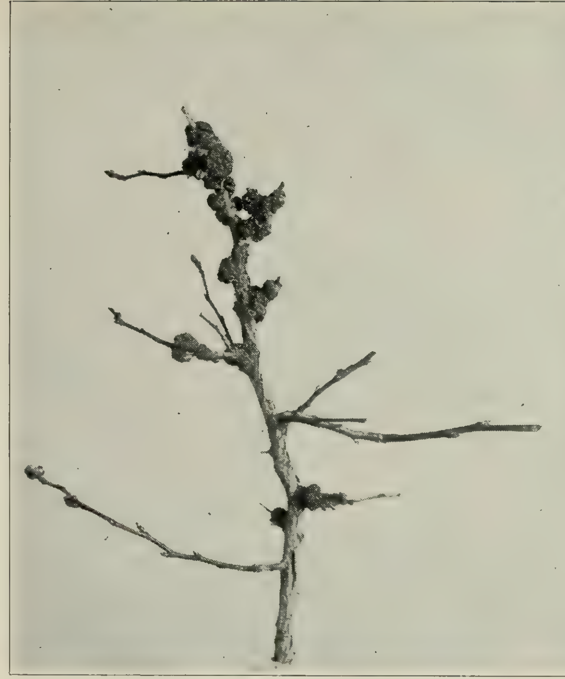


Figure 9. Crown Gall, a Bacterial Disease Caused by Bacterium tumefaciens.

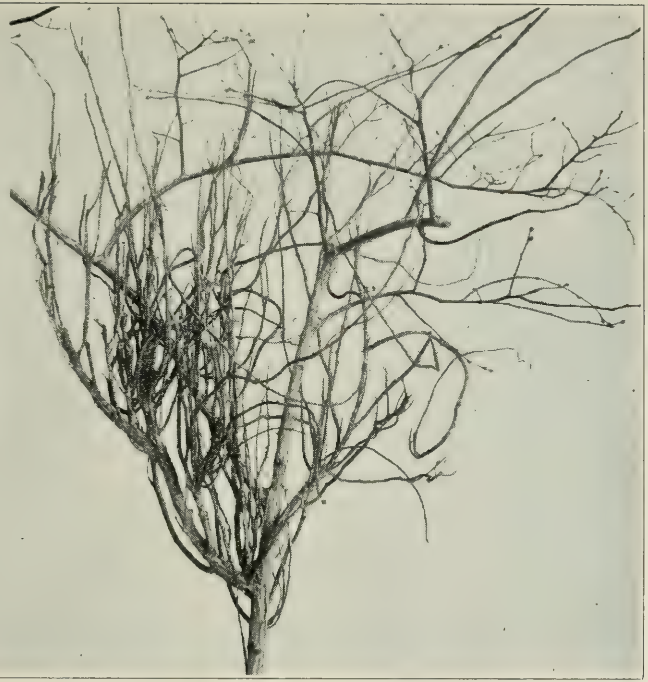


Figure 10. Witches Broom, Caused by the Rust Fungus, Calyptospora columnaris.

Birds, particularly robins, are among the worst pests of cultivated blueberries. In small plantings they sometimes take a large portion of the crop. In large plantings their depredations are not so noticeable. A few bushes can be protected by covering with netting, but no method has been developed for protecting large fields.

Marketing

Most of the wild blueberries marketed come from five states. The areas in blueberries and the production given by the 1930 Census are as follows:

	Area in acres	Yield in Quarts
Maine	13,888	3,810,806
Florida	2,014	366,585
Massachusetts	1,374	121,561
New Hampshire	902	171,268
Michigan	875	200,471

In all of these states there are undoubtedly large areas of blueberry land which are not included in farms and therefore not reported in the census. The yield figures are for 1929 only and do not give as accurate an idea of production as would an average over a period of years.

At present cultivated berries are produced mostly in New Jersey, which has about 500 acres. There are also small areas in Massachusetts, North Carolina, Washington, and Michigan.

New Jersey produces enough cultivated blueberries to ship them freely into most of the principal eastern markets. It is probable that the production in that state will double in the next five years as the many young plantings come into bearing. Also a considerable expansion of present plantings is anticipated, mostly of late varieties to minimize competition with fruit from North Carolina.

In North Carolina there is a small acreage of cultivated blueberries which probably will be increased considerably in the next few years. Most of the new plantings are of early varieties.

Although there is not yet a very large acreage of cultivated blueberries in Michigan, the industry is developing there and will more and more supply the demands of the Middle West, tending to limit the shipments from New Jersey to that section.

As production of cultivated berries increases, prices will probably fall nearer to those of wild berries. The producers of wild berries may attempt to improve the quality and attractiveness of their pack to meet this competition. This tendency has already been observed in certain markets where wild berries of good quality have been offered for sale in attractive packages.

Furthermore, cultivated blueberries are, for the present at least, distinctly a luxury crop. They have sold at from twenty to sixty cents a quart, the average price for 1934 being about thirty cents; while wild berries sold mostly from ten to twenty cents a quart. As long as the present general economic situation continues, the cultivated berries will not command the price premium which could be expected in more prosperous times.

Although the high prices received in the past will probably not be obtained in the future, the experience of those now growing cultivated blueberries indicates that they will yield a reasonable return on the investment if the grower uses care in establishing and managing his plantation. In addition to the points already discussed, the prospective grower should consider the following: the planting of late varieties will reduce to a minimum competition from berries shipped in from farther south; the planting of varieties such as Rubel and Wareham, which are easily and cheaply pruned, will keep down production cost; care in the location of plantings will help to prevent costly failures; location near main-traveled roads will facilitate the sale of berries on roadside stands at retail prices.

The Improvement of Wild Highbush Blueberries

There are many acres of wild highbush blueberries in this State where the bushes are yielding much below their capacity because of lack of a little care. Such bushes can be made to double or triple their yields without great expense or much labor.

In 1926 experiments were laid out on wild blueberry land in Hubbardston, Royalston, Westminster, Ashburnham, and Barre, Massachusetts, in an attempt to increase the yield of wild buhses. The general improvement program was as follows: (1) all large trees and second growth which shaded the blueberries were removed, (2) the bushes were pruned, (3) fertilizer was applied. The severity of pruning varied from removing twenty-five percent of the bush to cutting the whole bush to the ground. The fertilizers used were: nitrate of soda, ammonium sulfate, urea, calurea, cyanamid, 4-8-4, and nitrophoska. Also different combinations of fertilizers and pruning were tried.

The following results of this work were observed:

1. Removal of competing vegetation increased the growth of the blueberry bushes.
2. Pruning, if not too severe, increased the growth and yield of the bushes. The removal of more than about twenty-five percent of the bush was too severe. Bushes cut to the ground yielded a few berries the third year thereafter but required four years to produce a commercial crop.
3. Fertilization increased the growth and yield of the bushes. These increases seemed to be due to the nitrogen rather than to any of the other fertilizer elements.
4. A combination of fertilization and pruning was much better than either alone.
5. The increase in production on the fertilized plots was due mostly to increase in number of berries per bush. Under the conditions ot the experiment it was impossible to obtain satisfactory comparative yield records. The bushes varied both in size and number per acre. In spite of the fact that pickers were assigned to different parts of the field, they picked in the fertilized plots whenever possible, with or without permission. This is very good evidence of the better picking found there.
6. The berries on the fertilized plots tended to be larger. However, the size of the wild berries varies greatly due to inherited characters and cannot be increased beyond the limits set by these characters.
7. Fertilized bushes had a marked tendency toward annual bearing; unfertilized bushes toward biennial bearing.
8. The berries on the fertilized plots were firmer during dry periods than those on unfertilized plots.
9. A terminal shoot growth of about ten inches was most favorable. Since

the fruit buds are borne on the terminal third of the shoots, any increase in length up to ten inches increased yields. Shoots making a growth of over ten inches were apt to be too vegetative for maximum production.

These observations furnish the basis for the following improvement program:

First, remove from the blueberry land all trees and any bushes which grow high enough to shade the blueberries. The winter's wood supply can often be cut on the blueberry land, thus making the labor serve a double purpose. If trees valuable as timber are present, the owner will have to choose between more blueberries and more timber. If time permits, it will help to mow the low bushes which are growing in with the blueberries.

Second, prune the blueberry bushes. This should be done in winter or early spring before growth starts. Take out all dead wood first, then remove some of the oldest branches, cutting them off about four or five inches from the ground. This can be done to best advantage with a pair of heavy, long-handled lopping shears.

Third, fertilize the bushes. Until further information is available, a nitrogenous fertilizer is recommended. Apply nitrate of soda at the rate of 200 pounds per acre, or some other nitrogenous fertilizer at a rate which will give an equivalent amount of nitrogen.

Fourth, select and tag the more productive bushes and give them more attention when pruning and fertilizing.

Literature

1. Beckwith, C. S. and Stanley Coville. Blueberry culture. N. J. Agr. Expt. Sta. Circ. 229. 1931.
2. Beckwith, C. S. and C. A. Doehlert. Fertilizer and tillage for blueberries. N. J. Agr. Expt. Sta. Bul. 558. 1933.
3. Crowley, D. J. Observations and experiments with blueberries in western Washington. Wash. Agr. Expt. Sta. Bul. 276. 1933.
4. Diggers, B. F. Notes on the life history and habits ot the blueberry stem borer, Oberea myops Hald., on cultivated blueberries. Jour. N. Y. Ent. Soc. 37: 67–74. 1929.
5. Franklin, H. J. Cape Cod cranberry insects. Mass. Agr. Expt. Sta. Bul. 239: 54–62. 1928.
6. Johnston, Stanley. The propagation of the highbush blueberry. Mich. Agr. Expt. Sta. Spec. Bul. 202. 1930.
7. Johnston, Stanley. The cultivation of the highbush blueberry. Mich. Agr. Expt. Sta. Spec. Bul. 252. 1934.
8. Phipps, C. R. Blueberry and huckleberry insects. Maine Agr. Expt. Sta. Bul. 356. 1930.
9. Ware, L. M. Propagation studies with the southern blueberry. Miss. Agr. Expt. Sta. Bul. 280. 1930.

Publication of this Document Approved by Commission on Administration and Finance
3m. 5 '36. No. 7768.

VIRGINIA POLYTECHNIC INSTITUTE
AGRICULTURAL BRANCH LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 318 May, 1935

Onions In the Connecticut Valley

By A. B. Beaumont, M. E. Snell, W. L. Doran,
and A. I. Bourne

Proper cultural practices and the control of insect pests and diseases are determining factors in successful crop production. The investigations summarized here were planned to supply basic information in regard to these points in the growing of onions in the Connecticut Valley.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

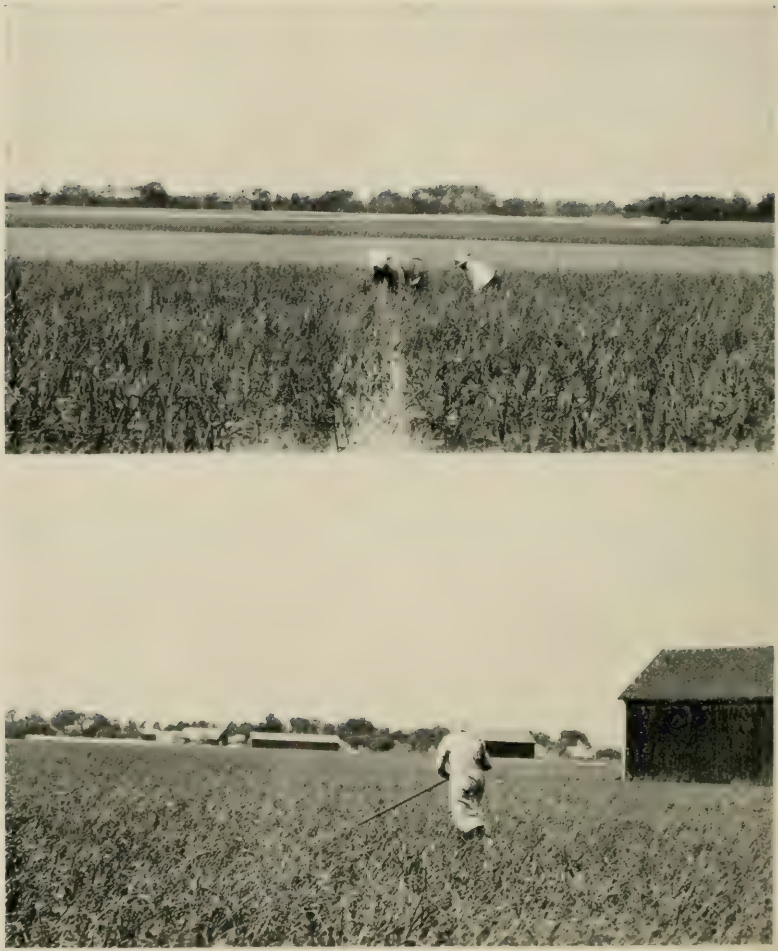


Figure 1. Women and children of the first and second generation Polish and Lithuanian immigrants do much of the hand work in onion culture in the Connecticut Valley.

Upper: Woman and child weeding onions.

Lower: Woman shove-hoeing onions. (Photographs taken June 11, 1925.)

ONIONS IN THE CONNECTICUT VALLEY

By A. B. Beaumont, Professor of Agronomy, M. E. Snell, Technical Assistant in Agronomy, W. L. Doran, Research Professor of Botany, and A. I. Bourne, Research Professor of Entomology[1]

FOREWORD

Massachusetts has been one of the leading states in production of onions for a hundred years or more. Until 1885 the center of production in this State was in Essex County, from which came the well-known Danvers Yellow Globe variety still important in the Connecticut Valley. Arthur L. Dacy of the Essex County Agricultural School has furnished information which appears to establish the place of origin of the Danvers Yellow Globe onion as the town of Danvers, Massachusetts, and the time prior to or about 1850. It was apparently a selection from the common yellow variety, made by Daniel Buxton. Although production of onions in the Connecticut Valley began some years earlier, it was not until 1885, when 111 acres were grown, that it became a commercial enterprise of importance. From then on the acreage expanded steadily, and from 1895 the Valley has been the leading center of production in the State. Thus, within half a century a new and important agricultural industry has been developed in the Connecticut Valley.

Onion culture in the Connecticut Valley developed on an extensive scale first in the town of Sunderland, which is still one of the leading towns in the production of onions. The onion acreage of the Valley is almost wholly confined to five contiguous towns in southern Franklin and northern Hampshire Counties: Sunderland, Deerfield, Whately, Hatfield, and Hadley. The fertile, level to gently rolling alluvial soils common in this area are well adapted to the intensive culture required in onion growing.

An important factor which contributed to the development of the onion industry in the Connecticut Valley was the influx of Polish and Lithuanian immigrants. Onion farming, requiring much hand labor, particularly laborious weeding, and little capital investment, was especially suited to the habits, temperament, and experience of these people. Now that immigration has been highly restricted and second and third generations of Poles and other recent immigrants are displacing the first generation, it will be interesting to see what the future trend of the onion industry in this Valley will be.

The peak of the onion acreage in the Connecticut Valley was reached in 1920 when 4850 acres were grown. Since that time, due to a number of poor years for the grower caused by low yields or low prices or both, the acreage has fluctuated widely between the high point of 1920 and a low point of 2520 acres in 1931. Owing to the small capital investment required for growing this crop, it is one whose acreage fluctuates widely in response to natural and economic factors. Prior to 1920 about 90 per cent of the onions of the Valley were grown from seed.

---

[1] Appreciation is expressed to the Onion Advisory Committee, composed of onion farmers, C. F. Clark, Chairman, Arthur Hubbard, W. W. Sanderson, Harry Welles, and Oscar Belden; and to G. B. Snyder, J. P. Jones and members of the Experiment Station Staff, for valuable advice given in the conducting of these experiments.

Since that time the acreage of onions grown from sets has increased rapidly, and largely at the expense of the acreage grown from seed. Recently the acreage of "set" onions has exceeded that of "seed" onions. Reasons for this shift were earliness for market and greater chance of securing a good crop by avoiding attacks of thrips and the often disastrous effects of "blast" and downy mildew.

Among the practical problems facing the grower of onions in the Connecticut Valley when the experiments reported in this bulletin were started were some related to production. These included the use of lime, the choice and method of applying fertilizers, value of cover crops, spacing, growing of sets, and improvement of onions by breeding and selection, as well as diseases and insect pests. The results of experiments concerned with these problems are reported in the following pages.

EXPERIMENTS WITH FERTILIZERS FOR ONIONS[1]

Soil Conditions and Plan

These experiments were conducted on an alluvial soil classified as Agawam fine sandy loam. It has a brown surface soil and a light brown, yellow or gray subsoil. This soil type has a rather uniform texture to a depth of three feet or more, is comparatively free from stones, has a level to slightly rolling topography, and poor to fair natural drainage. The drainage of the experimental field was improved by a system of tile drains installed prior to the beginning of the experiment. The organic matter content of the soil at the beginning of the experiment was 5.9 per cent and the reaction was pH 5.3. It contained 8.2 per cent clay, 58.4 per cent silt, and 33.4 per cent sand. In practically all respects except content of organic matter, which was slightly higher than that of most onion soils of the Connecticut Valley which have grown onions a number of years, this soil is typical of the onion soils of this region.

During the 20-year period preceding the experiments reported herein, the experimental field was in pasture most of the time, but corn was grown for two years immediately preceding the beginning of the experiment with onions. The field was seeded to mixed grasses and clovers sown in the standing corn the year before starting the onion experiment. The new seeding grew well during the fall, and was plowed under a few weeks before seeding onions in the spring of 1925. The field was limed in 1908 and again lightly in 1922. From 1908 to 1922 little or no fertilizer was applied, but a moderate amount was given the two crops of corn grown in 1923 and 1924.

The field was divided into plots having an area of approximately 1 square rod each, and arranged according to the chess-board plan. Each plot was 18′ 5″ x 18′, but this allowed a border zone around each plot, leaving a harvested portion of exactly 1 square rod. Plot treatments were replicated a minimum of 4 times[2], but, as indicated later, some treatments, particularly checks, were replicated more frequently.

Difficulty was met in the interpretation of the data on yield, especially of onions grown from seed. The "seed" crop, requiring a longer growing season than the "set" crop, is particularly open to the attack of thrips and to the disastrous effects of "blast". One or both of these factors caused poor yields of seed onions in the period 1925-1928. Only in 1929 was a good crop of "seed" onions obtained; and it was largely on account of the difficulty in securing a good crop from seed that the use of sets was adopted in 1930. Although insects and disease badly reduced the yield of onions, these factors affected the entire field more or less uniformly in any one year, and, therefore, it was thought a fair procedure to draw conclusions from relative yields from the different treatments. A statistical study of the figures on yield showed considerably more variation in the results from "seed" onions than from "set" onions, and consideration was given individual cases in the interpretation of results, as appears later. The Danvers Yellow Globe type was used for "seed" onions, and "Japanese" commercial sets for the "set" type[1].

---

[1] Credit is given for valuable assistance rendered in the early years of the experiments by Drs. O. E. Street and J. P. Jones, and Messrs. T. R Swanback and R. M. Horne.

[2] Except the 4-7-4 treatment which was replicated 3 times.

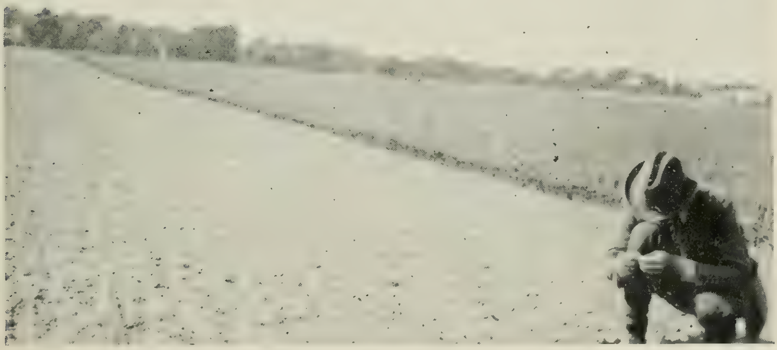


Figure 2. On left "seed" onions, on right "set" onions, photographed June 11, 1925. Note difference in stage of development: "seed" onions smaller than a lead pencil; "set" onions with well-developed tops.

These experiments were expected to yield information on the following points of particular importance in onion culture in the Connecticut Valley:

1. The effect of lime.
2. The most desirable ratio of nitrogen, phosphoric acid and potash in mixed fertilizers.
3. Organic versus inorganic carriers of nitrogen.
4. Deferred application of a portion of the nitrogen fertilizer.
5. Medium-analysis versus high-analysis fertilizers.
6. Muriate of potash versus sulfate of potash.

Results of experiments covering these points are presented below.

---

[1] The terminology used in connection with Connecticut Valley onions may be confusing because of more or less ambiguity in the use of the word "set". In this bulletin "seed onions" are those grown from seed sown in the spring of the year in which the mature bulbs are harvested; "set onions" are those grown from small sets produced in the preceding season.

The Effect of Lime

Owing to the importance of the question of the value of lime in Connecticut Valley onion culture at the time these experiments were started, particular attention was given it in the planning of the experiments. In all experiments with fertilizers and cover crops, two contiguous plots were treated as one plot in respect to the fertilizer treatment, but the south half received lime in addition, while the north half received fertilizer only. This difference in liming continued for three years (1925-1927), after which it was eliminated or reduced by liming the north half of each plot.

With the exception of the 6-8-4 treatment in 1926, where there was a slight but insignificant decrease in yield from the addition of lime, the favorable effect of lime was marked. The greatest increases occurred in 1927, following the second application of lime in the fall of 1926, when increases varied from 70 per cent to a little over 100 per cent. For the 3-year period (1925-1927) the mean percentage increase varied from 20.8 to 44.8 with a weighted mean increase of 34.8 per cent. In this series a large number of plots was involved, there being 19 check (4-8-4) plots and 20 others. This large number of repetitions reduces the probable error of the mean to a low figure. Mean differences of 10.0 per cent or more may be considered significant in this experiment.

For the purpose of determining the optimum dosage of lime for onions, an experiment was conducted with different quantities of lime varying from 0 to 7 tons per acre. The results showed a very definite and significant response of

NOTE ON STATISTICAL INTERPRETATION OF DATA FROM EXPERIMENTS WITH FERTILIZER AND COVER CROPS

In these experiments there were 19 check plots which were used throughout the experiment. In order to get a basis for judging the reliability of the numerical results of the experiments the data from the check plots, which were well distributed over the experimental field, were studied by conventional statistical methods.

In a study of this kind, the first thing to do is to see how nearly the data fit a normal distribution curve. The mean yields of onions grown from seed during the period 1927-1929 were first studied, and a bimodal curve was obtained with small or large classes. The mean yields of onions grown from sets in the period of 1930-32 gave a curve of normal shape but "skewed". These curves indicate that the data are not capable of strict statistical interpretation, and that results with onions grown from seed are less reliable than with those grown from sets.

However, in order to get some numerical basis for judging the reliability of the means obtained, certain constants were worked out by means of methods described in a previous bulletin* of this Station. The constants are as follows:

	Seed Onions			Set Onions		
	Mean	Probable error of the mean		Mean	Probable error of the mean	
	100's	100's	Percent	100's	100's	Percent
All checks	153.3	4.3	2.8	229.2	4.4	1.9
4 random checks.....(a)	141.8	7.7	5.4	219.2	8.3	3.8
Ditto......(b)	149.1	10.6	7.1	220.7	4.9	2.2
Ditto......(c)	181.5	4.9	2.7	200.8	3.2	1.6
Ditto......(d)	129.1	8.4	6.5	213.7	10.4	4.8

Constants approximating those obtained for random lots of 4 checks above were obtained for other lots of 4 receiving different fertilizers. Conventional treatment of these constants shows that in case of fertilizer treatments, differences of about 25 per cent between mean yields of checks and treated plots are necessary to be significant in the case of seed onions, and about 10 per cent in the case of set onions. Since the data are not capable of strict statistical interpretation, these figures were used as an aid but not a final criterion in evaluating the results.

---

*Beaumont, A. B., Snell, M. E., and Holland, E. B. The Effect of Certain Cropping Systems on the Yield and Quality of Havana Tobacco. Mass. Agr. Exp. Station Bulletin 297 (1933).

onions to 1 and 2 tons of lime. In the early stage of the experiment there was a definite response to the 3 or more tons of lime, but in the latter stages the advantages of the higher amounts became less.

To study effect of the different amounts of lime on the reaction of the soil, the pH values of soil samples drawn in 1925, 1928, and 1932 were determined. The figures indicated that it was difficult to raise the reaction of this soil above pH 6.4 by liming. Such a soil is said to be well buffered, and the buffer property is due to the presence of considerable fine mineral and organic matter. A soil containing more medium to coarse sand particles than this one would be expected to behave differently; the changes in pH values being greater.

The conclusion drawn from these experiments in the liming of a soil for onions is that on a soil of this kind and with approximately the same initial reaction (pH 5.3) lime is necessary, but little if any advantage may be expected from applications of lime above 3 tons. The optimum soil reaction range appears to be about pH 6.0—6.5. Once this range is attained, it can be maintained by an application of 1 to 2 tons of lime per acre once every 2 or 3 years. Less lime will be needed for the light sandy soils than for the heavier loams, but it must be applied more frequently. Ordinarily, it is better to apply the lime in the fall preceding the year in which the crop is to be grown rather than in the spring immediately before seeding. Tobacco requires a soil of lower reaction than is suitable for onions, and will not do well on soils limed correctly for onions. Similar deductions regarding the needs of onions for lime were made from a study of 114 Connecticut Valley farms in 1927[1].

Fertilizer Ratio Experiment

In this experiment the 4-8-4 grade[2] was chosen as the standard check and was supplied at the rate of 2500 pounds per acre. In this formula as well as the others in this experiment, one-half the nitrogen was from an organic source, animal tankage, and the other half was equally divided between nitrate and ammonium forms; the phosphorus was supplied by ammo-phos and superphosphate; and muriate of potash supplied the potassium. The fertilizer was applied broadcast and harrowed in before seeding or planting. Fertilizer grades used were: 4-8-4, 6-8-4, 4-12-4, 2-12-8, 4-12-8, 6-12-8, 4-8-8, 6-8-8.

From the first year of the experiment the 4-12-8 grade yielded the most onions, and the superiority of this grade continued throughout the experiment. Differences of about 25 per cent in yield of seed onions, and about 10 per cent in set onions, were necessary in order to be significant. The higher amounts of phosphorus and potassium produced significant increases only when used together in the same mixture. On account of the superiority shown by the higher amount of phosphorus, a still higher amount of that element was tried, but with no consistent advantage.

The response obtained from phosphorus applied to this soil is explained in part by the results of chemical analysis. Available phosphorus was determined by the Truog method[3] in samples drawn before the experiment was started, and in the spring of 1932. In the original soil there were 60 pounds of available phosphorus per acre, an amount considered low for best plant growth. Samples drawn in 1932 from plots which had received the 4-12-8 fertilizer showed 176 pounds, and from those which had received the 4-8-4 fertilizer 98 pounds, of available phosphorus[1]. Since a good crop (300 100-lb. bags) of onions removes only about 40 pounds of phosphoric acid, the soil in question must have had a very high fixing power. Presumably, after this fixing power becomes satisfied by repeated application of a high-phosphorus fertilizer the proportion of phosphorus in the fertilizer may be reduced.

---

[1] Jones, J. P. Liming onions. Mass. Agr. Exp. Sta. Bul. 237 (1927).

[2] These figures refer to perentages of nitrogen expressed as ammonia (NH_3), phosphoric acid (P_2O_5), and potash (K_2O) respectively.

[3] Truog, Emil. The determination of readily available phosphorus in soils. Jour. Amer. Soc. Agron. 23:788-799 (1931).

Since no advantage was shown by 6 per cent of ammonia over 4 per cent, an experiment was introduced to furnish further information on response of onions to nitrogen. The 4-12-8 was taken as the basis, and with it were compared a 2-12-8 and 6-12-8. The results showed no advantage from the extra nitrogen, while the lower amount appeared to be too low.

Organic versus Inorganic Nitrogen

A question of considerable economic importance in the selection of a mixed fertilizer is that of the nature of the nitrogen carrier. Organic fertilizer nitrogen usually costs considerably more per unit than does inorganic nitrogen. On this account the trend in recent years has been away from the organic forms toward the inorganic forms. In order to obtain some information on this point a 4-12-8 fertilizer composed entirely of inorganic materials was prepared and compared with the standard mixture of 4-12-8 which carried half its nitrogen in organic form. Considerable superiority was shown by the "organic" mixture in the production of seed onions and a slight though probably insignificant advantage with the set onions. This result appears to be closely related to the length of the growing season of the two types of onions. It is to be expected that the seed onions with a longer growing season would benefit more by the more slowly available organic nitrogen than would the set onions.

Side Dressing with a Nitrogen Fertilizer

It is a more or less common practice among growers in the Connecticut Valley to side-dress the crop with a nitrogen fertilizer about the first week of July, for seed onions, and the first of June for set onions. Fish meal is commonly used at the rate of 400 to 800 pounds per acre, but other nitrogen fertilizers are also used. An experiment was conducted for the purpose of comparing side-dressing with no side-dressing, and an organic with an inorganic carrier of nitrogen. Fish meal and sodium nitrate were chosen as the materials, and enough of each was added to furnish nitrogen equivalent to 50 pounds of ammonia per acre. The sodium nitrate was added to plots which had previously received an initial treatment of 4-8-4 fertilizer, but the fish meal, because it contained a small amount of phosphoric acid, was added to an initial application of 4-7-4. In this way the total nutrients applied in the comparative treatments were equal, and were equivalent to a 6-8-4 fertilizer.

First, it was noted that set onions were not benefited by the extra nitrogen. This result is as might be expected. Set onions ordinarily make their maximum vegetative growth by about July 1, and from then on to maturity little nitrogen should be needed for the "bottoming out" growth, which consists largely of storing carbohydrates. Second, it was noted that benefit was derived from the extra materials by the seed onions, but there was considerable variation in results. On the whole the sodium nitrate was superior to the fish meal, but there was one year (1927) in which the fish meal was superior.

---

[1] Determinations made by John N. Everson.

These results appear to be correlated with the distribution of the rainfall in the growing seasons concerned. In August of 1927 the rainfall was 5.01 inches, against a normal of 4.24 inches. Possibly this excess of rainfall was sufficient to throw an advantage to the more slowly available organic nitrogen. But the summer of 1928 was excessively wet and cool, the rainfall for the three summer months being almost twice the normal, and the organic material was much inferior to the inorganic carrier. Likewise, in 1929, a year as dry in contrast as 1928 was wet, the organic material was inferior. In both years nitrification was probably inhibited to such a degree that the full effect of the organic material was not obtained, and it was, therefore, inferior to the sodium nitrate although some of the latter may have been lost through leaching.

By comparing these results with those from the 6-8-4 used in the fertilizer ratio experiment some advantage seemed to lie with addition of part of the nitrogen as side dressing. The experiment as a whole appears to justify the conclusion that side-dressing with a nitrogen fertilizer may be beneficial to seed onions but is not likely to help set onions. A nitrate is preferable to an organic material, and probably will give better results than any other form of nitrogen.

The interrelationship between the effect of different forms of nitrogen in fertilizers and the prevailing weather is probably delicately balanced, so that a slight shift of weather in one direction or another may radically affect results.

Single Strength versus Double Strength Fertilizers

When these experiments were started, concentrated or high-analysis, particularly double-strength, fertilizers were becoming important commercially, and questions as to their value in comparison with the ordinary mixtures were more or less common. It was decided, therefore, to include a double-strength mixture in the list of those tried. An 8-16-8 was mixed from urea, ammo-phos, and muriate of potash, and this was compared with the standard 4-8-4. The results from the two materials were almost identical. In this experiment, also, striking benefits from lime were noted.

Muriate versus Sulfate of Potash

An old question in connection with fertilizers is that of the carrier of potash. Shall it be the cheap muriate or the more expensive sulfate? On account of the peculiar importance of sulfur in the formation of certain volatile oils found in onions, it was decided to make a comparison between the muriate and sulfate forms of potash as onion fertilizers. No significant differences were found in the yields from the two sources of potash. As in other experiments already noted, marked beneficial effects of lime were obtained.

COVER CROPS IN ONION CULTURE

In the culture of tobacco in the Connecticut Valley it is a rather common practice to make use of cover crops, and naturally the question of cover crops in onion culture has arisen from time to time. Tobacco culture and onion culture are quite different in most respects, but on account of the distribution of their labor requirements, a certain similarity in soil requirements, and a peculiar combination of economic and human factors existing in the Connecticut Valley, the two crops are grown in close proximity and almost exclusively of other crops.

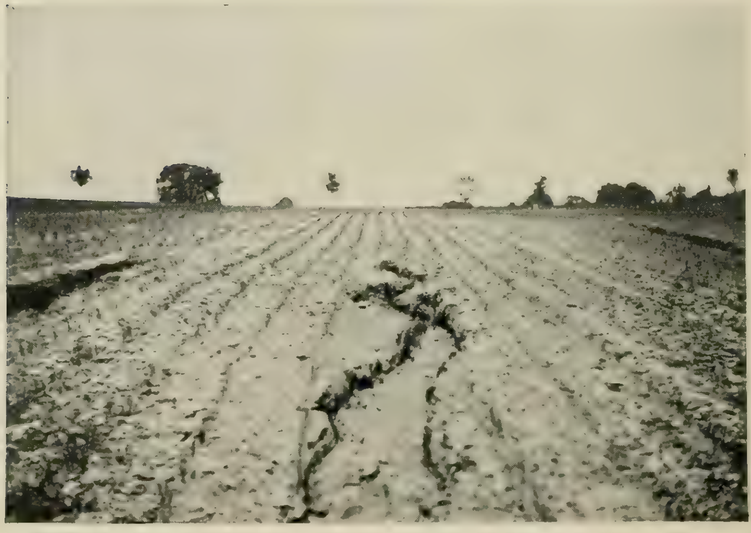


Figure 3. Water erosion of soil is not a serious problem on typical onion land of the Connecticut Valley, but occasionally it occurs, as shown by the above photograph.

Tobacco is usually harvested from about the middle of August to the first of September, the crop is removed, and it is an easy matter to sow a cover crop immediately. Seed onions are pulled from about the first to the middle of September, and are then allowed to cure in windrows for a month or six weeks before they are topped, sorted, and bagged. All operations are done in the field, and the bagged onions are left there some time before storing or marketing. Thus there is a practical difficulty in the way of growing cover crops in onion fields. This is less, however, with set than with seed onions because the former are harvested a month or so earlier, and are often marketed in time to grow a cover crop.

During the period 1926–1929 experiments were conducted with the following cover crops sown in seed onions: rye, timothy, redtop, crimson clover, and red clover. In addition, biennial sweet clover was tried one year, but it did so poorly that it was not tried again. These crops were sown immediately after a shove-hoeing about the last week of July. If the soil was rather dry and dry weather prevalent, the seed was worked into the soil by a second light shove-hoeing. Grass and clover seed were sown at the rate of about 40 pounds[1], and rye at 2 bushels per acre. With the exception of biennial sweet clover, growth was almost invariably good, grasses and clovers reaching a height of 3 or 4 inches, and rye 6 to 8 inches, before plowing in late fall.

---

[1] In practice this amount of seed could be reduced one-fourth to one-half.

With the exception of redtop all the cover crops depressed the yield of onions on the average, although there were years when gains were shown. The results were quite erratic, and the differences are not considered significant. It is interesting to note in this connection that redtop has proved the most satisfactory cover crop for tobacco in a separate series of experiments.[1]

It was found more or less difficult to cure onions in the presence of cover crops. Usually they were raked to a check plot without cover crop for curing, a method which would hardly be practicable on a large field. On a large scale the use of curing crates would probably be the most practicable method. Crates were tried in this experiment, but it was found that the onions did not cure quite so well in this way as on the ground.

This experiment has shown that it is possible to grow cover crops in the culture of seed onions in the Connecticut Valley. The cover crops, with one possible exception, have not proved beneficial to yield of onions, but this may be because the soil on which they were tried was a little better supplied with organic matter than the average onion soil. The cost of seed and additional labor in handling during curing are disadvantages of cover crops. Prevention or checking of water and wind erosion, particularly the latter, checking of losses of plant food by leaching, and increasing or maintaining the organic matter of soils, are possible advantages. Most likely, the use of cover crops would be more feasible and the advantage greater with set than with seed onions.

SPACING AND RATE OF SEEDING ONIONS[2]

As a result of observations made during preceding seasons relative to the effect of density of stand on the occurrence of onion "blast", a field test was conducted in 1929 for the purpose of obtaining further information on this point. Rows were spaced 13, 15, and 18 inches apart and it was planned to seed at the rate of 3, 5, and 7 pounds per acre. The field chosen for this work was quite uniform, and was uniformly fertilized with 2500 pounds of a 4-12-8 fertilizer. Each treatment was replicated four times.

The seeding was done May 11 at the actual rate of 3.5, 4.5, and 6.85 pounds per acre instead of 3, 5, and 7 pounds as planned. The different rates of seeding became very obvious soon after the onions came up and remained quite noticeable throughout the season. During July the number of plants on 90 feet of row were counted on each plot. The figures are given in Table 1, as well as the average number of seeds planted per foot and the average percentage which survived. Onions seeded at the heaviest rate matured about two weeks earlier than those seeded at the lightest rate. The wider spacing of rows also slightly retarded maturity. The crop was harvested 132 days after seeding, although some plots were still somewhat green.

Since there was no blast on onions during the season of 1929, the results were a failure so far as the effect of density of stand on blast was concerned; but there

---

[1] Beaumont, A. B., Snell, M. E. and Holland, E. B. The effect of certain cropping systems on the yield and quality of Havana tobacco. Mass. Agr. Exp. Sta. Bul. 297 (1933).

[2] Credit is due L. H. Jones and other members of the Botany Department for suggestions in planning the experiment.

TABLE 1. NUMBER OF SEEDS PER FOOT PLANTED AND NUMBER WHICH SURVIVED.

Rate of Seeding Pounds per Acre	Average Number of Seeds per Foot of Row	Average Number of Plants per Foot in July	Percentage Which Survived
3.50	11.37	5.64	50
4.50	14.62	7.35	50
6.85	22.25	10.69	48

was a good opportunity to study the influence of spacing on the quality and quantity of the crop grown. After clipping, the onions were graded into two sizes, above and below 1¼ inches, and weights taken. One hundred pounds of bulbs over 1¼ inches were also taken from each plot for further sizing. Table 2 shows the average yields for the different treatments. These data show that the heavier rates of seeding gave the heavier yields, but that a larger percentage of the yield was in the smaller sizes of bulbs. They also show that the greater distance between rows increased the percentage of large bulbs slightly, but that the area was used more advantageously when the rows were 13 inches apart than when they were 15 or 18 inches apart. This would indicate that from 4 to 5 pounds of seed per acre with 13 inches between rows should be most satisfactory.

TABLE 2. EFFECT OF RATE OF SEEDING ON YIELD AND SIZE OF ONIONS.

Rate of Seeding Pounds per Acre	No. 1 Bags* per Acre	No. 2		Percentage of No. 1's in Different Sizes			
		Bags* per Acre	Per cent	1¼ to 1¾"	1¾ to 2½"	2½ to 2¾"	2¾" and up
			Rows 13 Inches Apart				
6.85	386	23	5.4	39.4	56.9	3.7	0
4.50	369	11	2.8	26.5	66.5	7.0	0
3.50	352	5	1.4	22.3	67.8	9.9	0
			Rows 15 Inches Apart				
6.85	339	24	6.8	46.6	51.0	2.4	0
4.50	314	8	2.6	26.4	66.3	7.2	.1
3.50	262	4	1.6	19.2	69.1	11.6	.1
			Rows 18 Inches Apart				
6.85	318	13	4.9	37.4	58.5	4.1	0
4.50	269	6	2.3	21.9	68.4	9.3	.4
3.50	233	3	1.1	16.8	69.8	13.4	0

*100 pound bags.

THE EFFECT OF SIZE OF SET ON YIELD AND QUALITY OF CROP

In 1930 an experiment[1] was planned to determine the effect of size of set on yield, production of seed stalks, and production of doubles or divided bulbs; also the effect of breaking off seed heads on the yield and quality of the crop. Japanese onion sets, the type commonly grown in the Connecticut Valley, were graded into three sizes and planted on an area uniformly fertilized with 2500 pounds per acre of a 4-12-8 fertilizer. The plots were in quadruplicate, and on one half of each plot the seed heads were removed as they appeared, while on the other half the seed heads were allowed to develop. The size and average weight of the sets and the number of bushels required for planting per acre were as follows:

---

[1] This experiment as well as those on the growing of sets was conducted on Merrimac fine sandy loam.

	Size Inches	Weight Grams	Bushels per acre
Large	¾ to 1	6.3	94.84
Medium	½ to ¾	1.4	25.08
Small	¼ to ½	0.5	8.18

About three weeks after planting, a very marked difference in amount of growth could be seen, that from the largest sets being several times larger than that from the medium sets. Five weeks after planting, seed stalks from the largest sets were much in evidence, but none were showing from the medium or small sizes. Also, a considerable number of plants from the largest size were showing divisions, but relatively few from the medium size. During this time the seed heads were picked off at frequent intervals from the half of the plots having this treatment. About 60 days after planting, count was made of the number of plants having seed stalks or divided bulbs. The count was made on 100 consecutive plants in 5 different rows on each plot, or about 14 per cent of the entire population, and the results are given in Table 3. The figures show that removing the seed heads did not have a significant influence on number of seed stalks or divided bulbs, also that so many of the large sets developed seed heads or divided that the resultant crop of onions was of very poor quality. The number of sets in the other two sizes which developed seed stalks or divided was insignificant.

TABLE 3. PERCENTAGE OF ONIONS HAVING SEED HEADS AND DIVIDED BULBS 60 DAYS AFTER PLANTING.

Treatment	Size of Set	Percentage with Seed Stalks	Percentage with Divided Bulbs
Seed heads removed	Large	72.6	32.3
	Medium	1.2	1.5
	Small	none	0.1
Seed heads not removed	Large	73.3	33.8
	Medium	0.8	1.4
	Small	none	0.2

Ninety days after planting, most of the plants from the largest sets had fallen over; but as the medium and small sizes were still upright, pulling was delayed until 100 days from planting, and even then some of the small sets were still growing. This tendency of the larger sets to mature early is a very desirable factor under some circumstances. The tendency of sets of a similar size to start growing and come to maturity at the same time is a very good trait to be considered in the production of onions from sets.

At the time of clipping the onions, all having seed stalks were separated from those which did not. It is a pretty well-recognized fact that an onion bulb grown on a plant having a seed stalk is coarse and woody, and therefore of poor quality, compared to one not having a seed stalk. It was, however, observed that the bulbs were larger and of better quality when the seed head was removed at an early stage than when it was left on.

After clipping, the crop was graded according to size. Since the effect of the removal of seed heads was too small to be measured in the case of the bulbs from medium and small sets where but a very small percentage of seed heads was present, the two have been grouped together in the tabulation of the following data. Table 4 gives the yield of bulbs expressed in pounds per acre for the different grades and also the percentage of the different grades in relation to the total yield. This table shows that the removal of the seed heads appreciably raised the yield of onions where large sets were planted. On the plots where seed heads were removed, the weight of bulbs not having seed heads and over 1¼ inches was increased by 32 per cent, and the weight of bulbs not having seed heads and under 1¼ inches was decreased by 34 per cent. The percentage gain or loss was much greater when the weight of the poorer grades was included. Where the seed heads were removed, 44 per cent of the weight of the bulbs over 1¼ inches was produced by the 27.4 per cent not having seed stalks; and where the seed heads were not removed, 52 per cent of the weight of the bulbs over 1¼ inches was produced by the 26.7 per cent not having seed stalks. If only the bulbs over 1¼ inches and without seed stalks are considered, the large sets on the plots with seed heads removed produced 52 per cent, the large sets on the plots without seed heads removed 39 per cent, and the small sets 52 per cent as many pounds as did the medium sets.

TABLE 4. AVERAGE YIELDS PER ACRE AND PERCENTAGE OF GRADES.

Size of Sets	Plot Treatment	Total Bulbs		Bulbs over 1¼ inches	
		Pounds	Percent of all bulbs	Pounds	Per cent of all bulbs
		All Bulbs			
Large	Seed heads removed....	33,490	100	32,490	97
	Seed heads not removed	23,140	100	20,680	89
Medium	Both*.................	28,195	100	27,565	98
Small	Both*.................	15,760	100	14,270	91
		Bulbs Having No Seed Stalks			
Large	Seed heads removed....	15,000	45	14,310	43
	Seed heads not removed	11,840	51	10,800	46
Medium	Both*.................	28,005	99	27,375	97
Small	Both*.................	15,760	100	14,270	91

*The effect of seed stalk removal was too small to be measured: hence the two plots were not kept separate.

The removal of seed heads is desirable when large sets are used for planting. Even though a greater yield may be obtained, and in a shorter period, from large sets than from medium sets, a greater net income can usually be expected when medium sets are used, because the crop will be more uniform and of higher grade, and because the initial cost for sets is less on account of the smaller number of bushels required.

In 1931 a further study of the effect of size of set on yield and quality of the crop was made. Owing to the fact that so large a number of the sets generally sold for planting are outside of the size limits ½ to ¾ inch (termed medium in the previous experiment), the distributors of sets felt that they could not confine the size of sets sold to these limits without raising the price above what growers could afford to pay. They therefore compromised and made a grade from 3/8 to 7/8 inch which was sold quite extensively in 1931.

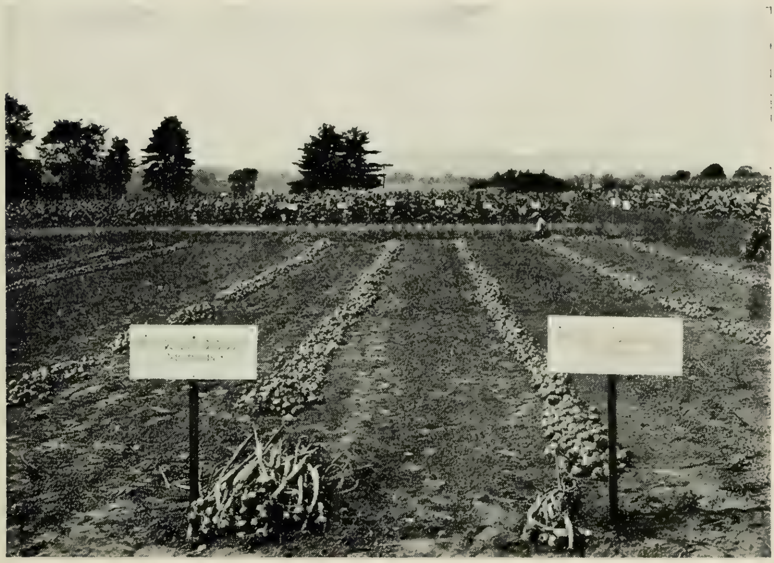


Figure 4. Comparison between commercial sets (left) and specially graded sets (right). Note number of onions with seed stalks (piled by the signs) produced from the two sizes of sets.

A field test was conducted to compare these commercially graded sets with sets graded from ½ to ¾ inch. The field was fertilized with 2500 pounds per acre of a 4-12-8 fertilizer, and each treatment was replicated 10 times. The 3/8- to 7/8-inch size required 28.2 bushels of sets per acre, and the ½- to ¾-inch size but 25.5 bushels per acre. During the early summer, counts on 500 plants on each plot were made to determine the number of divided bulbs and seed stalks. After growing 95 days the onions were harvested. At the time of clipping, those having seed stalks were kept separate. The bulbs under 1¼ inches were screened out.

The yield from the two groups of sets was practically the same, it being 282.3 bags (100 pounds each) from the ½- to ¾-inch sets and 287.5 bags from the 3/8- to 7/8-inch sets.

Table 5 gives the percentage of divided bulbs, of bulbs with seed stalks, and of the various grades. This test seems to show that though a considerable number of bulbs developed seed stalks or divided bulbs in the 3/8- to 7/8-inch group, they produced nearly as many pounds of bulbs over 1¼ inches and not having seed stalks as the ½- to ¾-inch size. The 3/8- to 7/8-inch sets also produced a large percentage of the bulbs in the smaller sizes. The difference in price of the two grades of sets would determine whether to buy those having the lesser or the greater range in size.

TABLE 5. PERCENTAGE OF DIVIDED BULBS, BULBS WITH SEED STALKS, AND GRADES OF ONIONS.

	Grown from ½- to ¾-inch sets Per cent	Grown from 3/8- to 7/8-inch sets Per cent
Bulbs divided (by count)	0.34	10.24
Bulbs having seed stalks (by count)	0.52	4.22
Bulbs over 1¼ inches having no seed stalks	97.4	94.7
Bulbs under 1¼ inches having no seed stalks	2.2	2.9
Bulbs having seed stalks (by weight)	.4	2.4
No. 1 bulbs*:		
Between 1¼ and 1¾ inches	2	5
Between 1¾ and 2¼ inches	30	33
Between 2¼ and 2¾ inches	58	51
Over 2¾ inches	10	11

*Sound onions without seed stalks were considered as No. 1.

PRODUCTION OF MORE DESIRABLE ONION SETS

The experiments just reported, on the influence of size of set on yield and quality of onions, emphasize the lack of accurate information regarding methods of growing desirable sets. The present methods are quite varied and usually meet with only partial success. It was, therefore, felt that this Station could well make some studies of factors thought to be important in the growing of sets. In a preliminary test in 1931 three variables were studied: rate of seeding, rate of fertility, and width of row. Seed was sown at rates of 50, 70, and 90 pounds per acre; grown without any fertilizer and with 500 pounds per acre of a 4-12-8 fertilizer; and with one-inch and two-inch rows.

The effect of the fertilizer became apparent early, and the fertilized plots looked better than unfertilized plots throughout the season, but the value of the other variables was much less apparent. The onions were pulled 106 days from planting, allowed to dry a few days, clipped, and taken inside where they were carefully graded into four sizes, under ¼ inch, ¼ to ½ inch, ½ to ¾ inch and over ¾ inch. The two-inch row produced considerably more sets than did the one-inch row, with the greatest increase in the larger sizes. The fertilized plots produced more weight of the most desirable size, ½ to ¾ inch, although not a greater percentage of the whole, than those not fertilized. The smallest rate of seeding produced the greatest percentage of sets of the most desirable size. It was clearly shown that a very large number of the sets did not make sufficient growth to reach the most desirable size. Either lighter seeding or greater fertilization would tend to remedy this, but would also increase the number of sets too large for planting. After storage of about six months, the most desirable size was found to have suffered the least loss from sprouting and decay. Also, the fertilized sets kept slightly better than those not fertilized.

During the next two seasons more extensive experiments were conducted. Treatments and results are given in Table 6. From these experiments it was clear that a definite balance between the food supply and the population must be maintained in order to produce maximum yields of sets having a high percentage of a desired size. With 500 pounds of the 2-12-8 fertilizer, 40 pounds of seed per acre were adequate, but 50 pounds were needed with 500 pounds of the 4-12-8. With 500 pounds of the 0-12-8 fertilizer neither total yield nor yield of the desired size was so high, but a high percentage fell within the desired size, especially with 30 or 40 pounds of seed per acre. In general 30 pounds of seed per acre were not enough for best results, and it is rather doubtful whether the 3-inch spread increased the yield enough to warrant the extra trouble of planting and caring for the wider row.

Some of the sets produced were stored for about six months to determine their storage quality. The storage loss was found to be least with the larger sizes. This was not quite in agreement with the results from the crop of 1931, but may perhaps be explained by the absence of sprouting in the crops of 1932 and 1933, while there was considerable sprouting in that of 1931. The 1932 sets grown with the 0-12-8 fertilizer showed a much greater loss than those grown with any of the other fertilizers in every size, but those of 1933 showed no material difference between the fertilizer treatments.

Some sets of the two larger sizes from each of the fertilizer treatments were planted in the field in order to observe their behavior in comparison with sets of the same size from a lot which had been commercially grown. The principal factors observed were dormancy as shown by readiness to grow when planted, tendency to develop seed stalks, tendency to split making multiple bulbs, and yield and quality of bulbs.

TABLE 6. PRODUCTION OF ONION SETS—2-YEAR AVERAGE.

Fertilizer Treatment	Pounds of Seed per Acre	Width of Row Inches	¼- to ½-inch Sets		½- to ¾-inch Sets		Total Bushels per Acre
			Per cent of Total Yield	Bushels per Acre	Per cent of Total Yield	Bushels per Acre	
500 lbs. 4-12-8	30	1	6	29.6	36	181.9	501.9
		2	6	26.2	38	178.7	467.7
		3	5	25.6	38	193.2	511.3
	40	1	10	52.6	48	255.2	529.7
		2	10	53.2	50	273.3	543.3
		3	10	56.6	50	277.7	522.9
	50	1	15	78.6	53	275.2	516.3
		2	15	85.5	56	312.8	556.3
		3	15	83.2	58	330.1	570.9
	Average	1	10	53.6	46	237.4	515.9
		2	11	54.9	49	254.9	522.4
		3	10	55.1	49	267.0	545.0
	30	Average	6	27.1	37	184.6	493.6
	40		10	54.1	50	268.7	542.0
	50		15	82.4	56	306.0	547.8
500 lbs. 2-12-8	30	2	10	52.8	54	276.8	512.4
	40	2	17	96.7	60	334.6	554.1
	50	2	24	133.8	61	325.8	530.7
500 lbs. 0-12-8	30	2	16	66.4	59	251.5	428.7
	40	2	23	102.2	58	264.0	452.9
	50	2	33	141.2	57	249.2	436.0
1000 lbs. 4-12-8	40	2	10	56.3	49	294.3	599.3
	50	2	14	87.8	51	313.2	615.4

The commercially grown sets started more readily, and the large size, ¾ to 1 inch, was ahead of the smaller size, ½ to ¾ inch, all season so far as top growth was concerned. The greatest difference observed, however, was in the number of seed stalks and multiple bulbs produced, which was determined by actual count during the latter part of the growing season. The percentages of seed stalks and multiple bulbs are given in Table 7, for the two-year average. The 1932 sets showed much greater differences between fertilizer treatments regarding the development of seed stalks and multiple bulbs than did the 1933 sets. This can be explained by the fact that in 1933 care was taken to select for planting sets having an equal weight, but the 1932 sets were taken at random and would therefore in some cases have a larger number of the sets near the upper or lower limit of size. Table 7 shows that neither seed stalks nor multiple bulbs were an important factor with well-grown sets under ¾ inch, but when larger sets were used they may become so numerous as to seriously reduce the value of the crop, for a set which develops a seed stalk or divides will never become a first grade onion.

Table 7 gives also the yields per acre of several different grades of onions produced. The bulbs over 1¼ inches and without seed stalks or divisions represent all of the first grade marketable bulbs and are a good basis upon which to judge the relative merits of the differently grown sets. The yields in this grade from the small sets showed no appreciable difference between the fertilizer treatments, and in only one case with the large size was the yield of first grade bulbs reduced much below that of the small size. In other cases the large sets gave approximately the same yields of first grade onions as the small size and in addition several hundred pounds of second grade onions. The commercially grown sets did not do quite as well as the Station-grown sets.

TABLE 7. A TWO-YEAR COMPARISON OF ONIONS GROWN FROM COMMERCIAL SETS AND FROM SETS PRODUCED UNDER EXPERIMENTAL CONDITIONS.

			2-Year Average Yields, Pounds per Acre				
Fertilizer Treatment per Acre under Which Sets Were Grown	Percentage Having Multiple Bulbs	Percentage Having Seed Stalks	Bulbs without Seed Stalks		Multiple Bulbs	Bulbs Having Seed Stalks	Total
			Over 1¼ inches	Under 1¼ inches			
Sets ½ to ¾ inch in Size							
500 lbs. 0-12-8	0.19	1.21	40,938	105	48	478	41.569
500 lbs. 2-12-8	0	1.08	39,312	153	0	420	39,885
500 lbs. 4-12-8	0.36	1.34	39.886	105	114	478	40,583
1000 lbs. 4-12-8	0.55	0.82	39,934	19	239	335	40,528
Commercial	0.91	2.74	36,969	230	411	813	38,423
Sets ¾ to 1 inch in Size							
500 lbs. 0-12-8	2.56	17.86	39,981	57	976	6,963	47,978
500 lbs. 2-12-8	2.73	17.45	40,268	134	995	6,647	48,045
500 lbs. 4-12-8	1.84	18.69	39,312	67	708	7,011	47.098
1000 lbs. 4-12-8	6.18	24 70	38,260	9	1,894	8,350	48,513
Commercial	11.11	25.81	36,156	287	4,180	9,153	49,776

In 1934 an attempt was made to learn to what extent the size of sets could be controlled by pulling them when they had made sufficient growth rather than allowing them to grow till more mature, and also to observe the influence of this early pulling on keeping quality and performance when planted for bulb production. Later plantings of seed were also made to see how they compared with the more common practice of early planting. It was found that by planting heavily enough to get a thick stand and fertilizing with as much as 1000 pounds per acre on fairly good onion land, sufficiently good growth could be obtained for the production of vigorous sets of the proper size. It is, however, necessary to pull the plants before the sets have developed to the size wanted since they continue to develop for some time after pulling. This growth of the sets after pulling permits them to become well formed even though the plants may have been greatly crowded in the row while growing, but does necessitate a large vigorous top growth from which to develop the sets.

In 1934 the latest planting, May 15, was the most successful. The earlier plantings were seriously affected by the cold, wet weather in early May which, combined with a bad infestation of onion maggots, resulted in thin and poorly distributed stands. By planting somewhat later than is customary, good stands should be possible even with medium rates of seeding. Since the cost for seed in the growing of sets for planting is great, anything that lowers the cost without resulting loss is highly desirable.

The results indicate that very good yields of sets can be obtained locally, with a reasonably high percentage of a desired size; that they can be kept in storage without excessive loss from decay, sprouting, or shrinkage; and that when planted they will produce satisfactory onions.

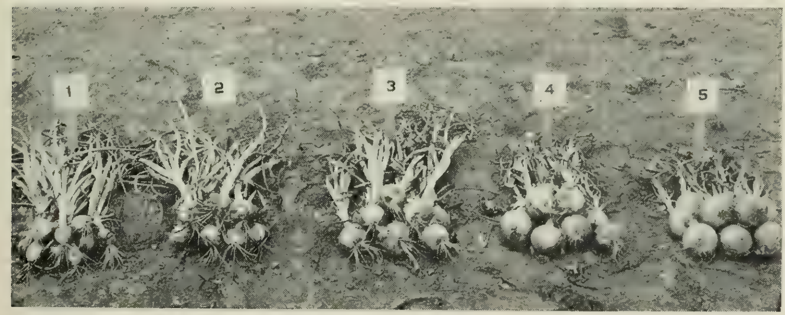


Figure 5.

No. 1. Common Yellow Globe onions grown from seed sown in the field.
No. 2. Same from a commercial improved strain of Yellow Globe.
No. 3. Same as No. 1 except seed started in greenhouse and transplanted to the field.
No. 4. Same as No. 2 except transplanted.
No. 5. "Japanese" onions grown from commercial sets.

ONION BREEDING AND VARIETY TESTING

For the past ten years varieties and strains of onions have been collected and grown for comparison and selection in a study of onion breeding. Many of the original strains and varieties have been discarded because they were not suited to local conditions or because they seemed to be inferior to other strains or varieties of a similar type.

Bulbs which seemed to have the desired qualifications were selected from the better strains or varieties and have been inbred, some of them for five generations. Several crosses have been made but with no great success. Some of the strains have become greatly weakened by the close inbreeding and do not produce seed

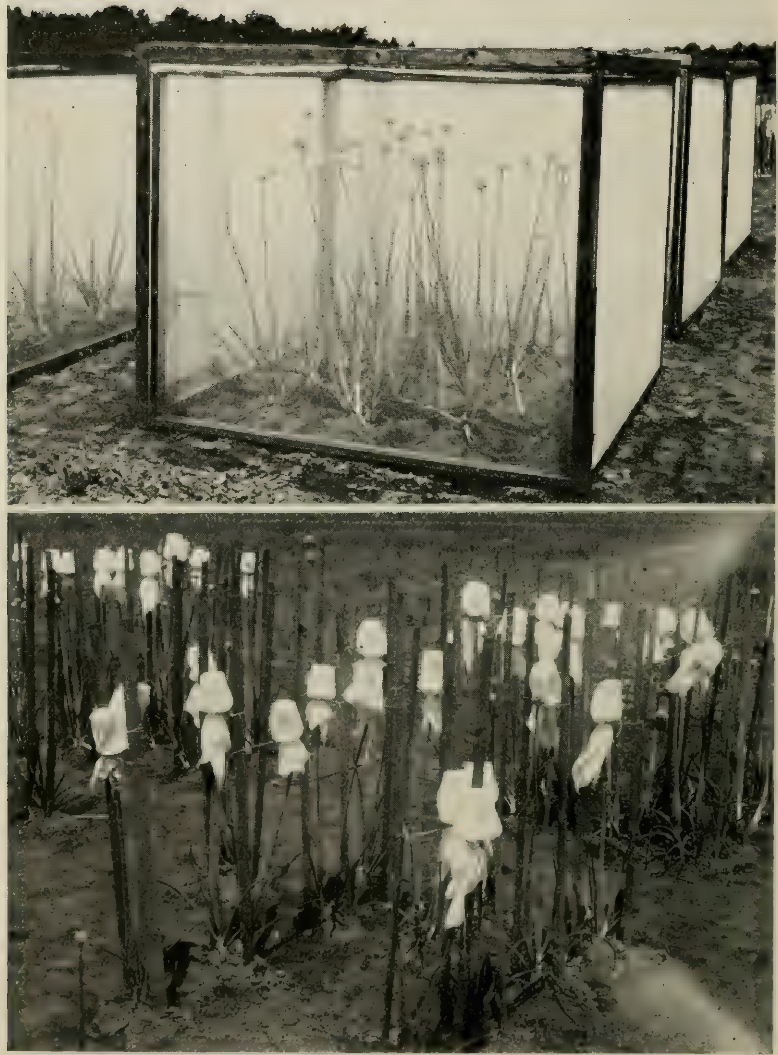


Figure 6. Methods used in onion breeding.

Upper: Frames covered with cheescloth, used in "mass" breeding.
Lower: Use of cheesecloth covers to protect flower head from cross pollination.

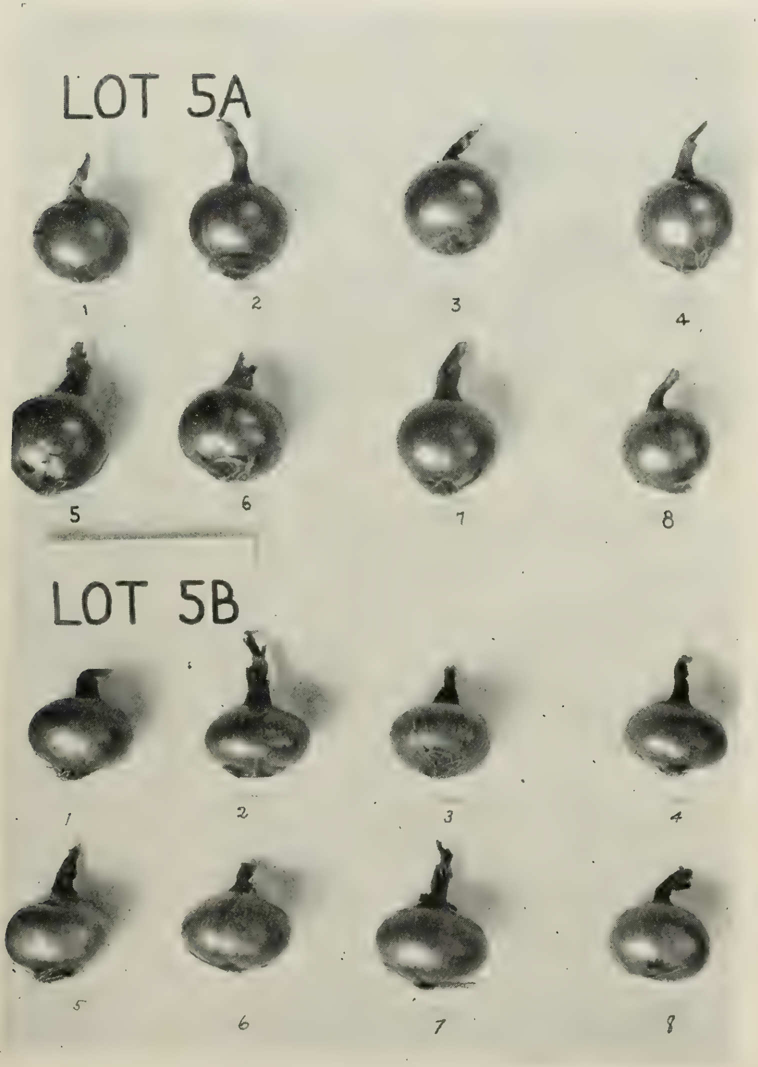

LOT 5A
1
2
3
4
5
6
7
8
LOT 5B
1
2
3
4
5
6
7
8

Figure 7. Onion bulbs selected for breeding.

Upper: Globe types.
Lower: Flat types.

at all freely when selfed or when crossed with some other strains; others have kept quite vigorous and grow and produce seed readily.

Several lots of inbred seed of the Japanese, or set type of onion grown locally, were planted for the development of sets for planting instead of for bulbs for seed production. This phase of onion development was undertaken because the Japanese (or Ebenezer) set is at present the principal type of onion grown here, and the set method seemed better suited to the development of onions for that purpose than the seed method which had previously been used entirely. This method requires three years per generation instead of two, as is the case with the seed method, but has a number of decided advantages.

The sets for planting have now been grown from inbred seed three years; sets have been planted for bulb production two years; and one crop of seed has been grown from bulbs produced from sets. Some difficulty has been experienced in getting good sets from small amounts of seed, but on several occasions very good sets have been grown. In growing strains from sets, marked differences were seen in seed-stalk and multiple-bulb development, particularly; but also in time of maturity, shape of bulbs, type of skins, and top growth, similar to those observed in seed onions but usually more marked because of the much more advanced stage of growth possible with sets. When the bulbs grown from sets were planted for seed production they did extremely well, partly because of the extra size and strength and partly because a much larger number had developed into good bulbs which gave a better chance for selection.

Another way of getting good-sized mature bulbs from the inbred and crossed seed was found to be starting the plants in the greenhouse in early February and later transplanting them to the field. This method gave very good results. A much higher germination of seed was obtained in this way and nearly every seed which germinated grew into a fair-sized bulb. These plants were very uniform in type during the growing season and produced a finer lot of bulbs than had ever been grown from seed sown in the field. The substitution of transplants for sets in commercial production appears to have possibilities. Some fairly large bulbs of the Sweet Spanish types, which when grown from seed require a longer growing season than prevails in the Connecticut Valley, have been grown in this way.

DISEASES OF ONIONS

The smut disease of onions, caused by the fungus *Urocystis cepulae*, has long been prevalent in the Connecticut Valley. As work at this Experiment Station[1] has shown, the disease is controllable by a solution of formaldehyde, 1 gallon diluted to 50 gallons with water. If the soil is dry, this is applied at the rate of 50 gallons per acre. If the soil is medium moist, 62½ gallons per acre should be applied, and for a wet and heavy soil 83⅓ gallons per acre is indicated. Details of the method of application are discussed in the bulletin mentioned.

Two of the most common diseases of onions in the Connecticut Valley are downy mildew, which is caused by the fungus *Peronospora schleideni*, and blast. Blast, or the premature death of the foliage, has usually occurred about the third week of July when periods of rain were interrupted or followed by high temperatures, bright sunlight, and drying winds. The disease is probably not caused by a parasite. On the basis of work done at this Experiment Station,[1] it is not recommended that onions be sprayed every year with a copper fungicide alone, for downy mildew and blast are not important here every year. It is suggested, however, that growers spraying onions for protection against thrips include Bordeaux mixture 4:4:50 in the combination spray.

---

[1] Anderson P. J., and Osmun, A. Vincent. The smut disease of onions. Mass. Agr. Expt. Sta. Bul. 221. 1924.

ONION THRIPS AND ITS CONTROL

The onion thrips is an outstanding pest in practically every region where the crop is grown on any commercial scale. It is always present and in seasons favorable for its development causes serious losses to the crop. In regions similar to the Connecticut Valley, the situation is aggravated by the very common practice of growing seed onions close to fields of sets. Set onions, because of their early start and rapid growth, are able to withstand thrips, the attack developing so near the time of maturity that the yield is seldom, if ever, seriously affected. Sets, however, offer a ready source of food and excellent breeding grounds for thrips. It is not unusual to find from 500 to 600 thrips on a single plant. As the set onions reach maturity, the insects migrate to young, tender plants of seed onions near by, where more serious damage is caused. Also this migration usually occurs at the period when the rate of reproduction of thrips is at its height.

Laboratory experiments with plants cleared of thrips and screened to prevent infestation from outside have shown that 150 to 200 young thrips may emerge from eggs imbedded in the leaf tissue during the space of five to six days. This accounts for the fact noted by many observers that, despite a high percentage of kill by an insecticide, fields often show a heavy reinfestation within a few days after the application. Very often this leads the grower to believe that the spray has been ineffective.

Effect of Environment on Abundance of Thrips

The two most important sources of infestation of seed onions are grassland and sets. Set onions offer excellent opportunity for the rapid multiplication of thrips during the early season, while grassland furnishes excellent hibernation quarters for the insects.

Repeated observations on the seasonal abundance of thrips in commercial plantings of seed onions exposed to either or both of these environments have invariably indicated the danger of early and heavy infestation from both sources. One such field, bordered on the one hand by set onions and on the other by grassland, showed at the time the sets were maturing and just after the field of grass was mowed an average of 1900 thrips per 100 plants in the rows next the sets and 1760 thrips in the rows adjoining grassland. In the center of the plot the average infestation was less than 600 thrips per 100 plants.

Studies throughout the season of a field of seed onions isolated from sets showed the number of thrips to be negligible up to the middle of July. From July 21 to 28 the number per plant averaged 25 to 40 and the infestation reached its peak during the week of July 28 to August 4, with an average of 42 thrips per plant. The plants in this field showed little or no injury and matured a good crop.

---

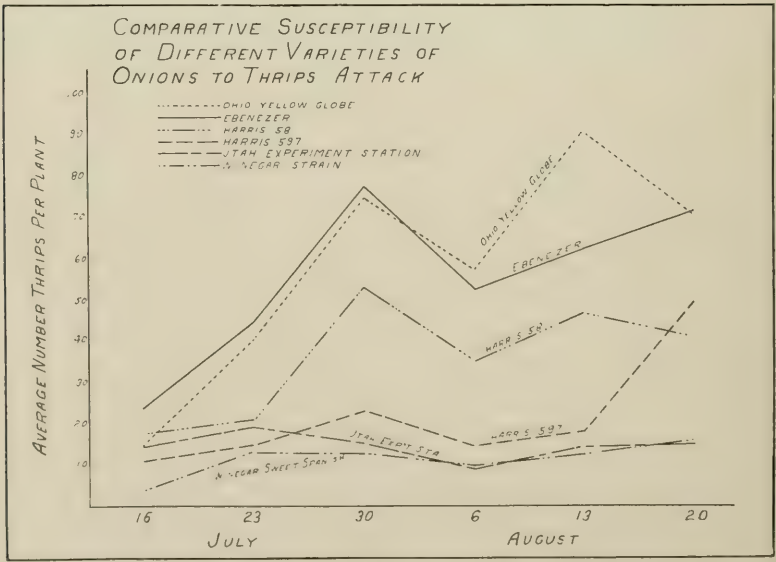
[1] Doran, William L., and Bourne, Arthur I. Onion spraying and dusting experiments. Mass. Agr. Expt. Sta. Bul. 279. 1931.

A similar field planted on the same day but located next to set onions showed an infestation of 35 thrips per plant by July 7. By July 14 the plants were becoming badly scored. The maximum infestation was reached on July 28 with an average of more than 80 thrips per plant. At that time the damage was so severe that the field was sprayed in the hope of securing at least a partial crop. The plants in this field were badly scarred and stunted. Their maximum growth amounted to little more than half that of the plants in the field isolated from sets and they matured a light crop of inferior-sized onions.

Susceptibility of Different Varieties and Types of Onions to Thrips Attack

It has been recognized for some years that extreme differences exist in susceptibility of different varieties of plants to insect injury. During the past year investigations of this phase of onion thrips control carried on in Massachusetts were of two types: (1) a comparative study of six varieties—Ohio Yellow Globe, Ebenezer, Harris No. 58, Utah Experiment Station Sweet Spanish, Harris No. 597 Riverside Sweet Spanish, and Winegar Strain Sweet Spanish—in their resistance to thrips attack, and (2) a similar study of different strains of Danvers Yellow Globe, the standard variety now being grown in the Connecticut Valley.

The different varieties were all planted the same day and were so located that they had equal opportunities for thrips infestation. Weekly counts were made of thrips abundance throughout the season. The observations are presented in the accompanying chart.



From these data it will be observed that the infestation on the two varieties, Utah Experiment Station and Winegar Sweet Spanish, was consistently lower than on the other varieties. Harris No. 597 ranked next, followed by Harris No. 58. It may be pointed out that throughout the growing season these four varieties had fewer thrips per plant than was the case in an adjacent field of

Danvers Yellow Globe. The remaining varieties, Ebenezer and Ohio Yellow Globe, proved as susceptible to thrips attack as the Danvers Yellow Globe.

It would appear likely that the type of growth of the plant has a great deal to do with the abundance of thrips. This theory is supported by the following facts. The susceptible variety Ebenezer exhibits a strong tendency for the leaves to curl, thus allowing protection to the thrips. The varieties Ohio Yellow Globe and Danvers Yellow Globe have tightly closed chits which likewise afford the thrips protection. Thrips-resistant varieties are characterized by upright growth and an open chit.

In different strains of the same variety, thrips abundance seems to be correlated directly with the presence or absence of a closed chit. This statement is based on a study of comparative resistance of different strains of one variety of onions. Examination of three plots of strain B, which had a pronounced upright type of growth, showed that on two of the plots the plants had open chits, on the third, closed chits. The following data represent the abundance of thrips during the first two weeks in August at the maximum period of thrips abundance.

Date	*Plot*	*Type*	*Average thrips abundance*
Aug. 1	B1+B2	Open chit	16
	B3	Closed chit	103
Aug. 8	B1+B2	Open chit	26
	B3	Closed chit	96
Aug. 14	B1+B2	Open chit	40
	B3	Closed chit	119

From the investigations thus far made, it would seem that a type of onion resistant to thrips attack should possess the following characteristics:

1. Growth upright without any tendency to curl;
2. An open type of chit; one not tightly closed by the growth of the young inner leaves.

Biological Control of Thrips[1]

Natural enemies of onion thrips, while prevalent in this region each year, have shown no appreciable value in checking the pest. The predacious insects collected included five species of lady beetles; lace wings, or Chrysopids; several species of Syrphid flies; and a predacious bug, *Triphleps insidiosus* Say, which has been recorded as feeding almost entirely on different species of thrips. In addition to these are several species of predacious thrips which undoubtedly are among the most effective of all the natural enemies attacking onion thrips.

While the above list undoubtedly does not include all the species that may prey upon thrips, it indicates that several natural enemies of that pest are well established and generally distributed throughout this region. Unfortunately their numbers are so insignificant as compared with the thrips that they exert little influence upon the infestation.

Attempts by several growers to liberate large numbers of a species of lady beetle, *Hippodamia convergens*, procured from dealers in Colorado were unsuccessful, largely because the beetles upon liberation immediately spread over a wide area and did not confine themselves to the fields where they were released.

---

[1] Credit is given to F. R. Shaw for his observations on seasonal abundance and biological studies on this disease.

In the late summer of 1932 a parasitic fungus was discovered to be attacking onion thrips throughout onion fields in the Connecticut Valley. This appeared in considerable abundance about August 1 and continued to be prevalent up to the close of the growing season. The first evidence of its presence was a slowing up in activity and general sluggishness on the part of the infected thrips. Subsequent examination revealed the presence of a fungus in these dead and dying thrips, and microscopic examination in the laboratory showed the bodies to be completely filled with the mycelium of the fungus. During the remainder of the season it was found that the fungus was well distributed throughout the onion growing section of the Connecticut Valley. Studies on the thrips abundance for the season revealed that from approximately the middle of August the decline of numbers of thrips, instead of following the usual curve established by life history studies over a period of years, dropped off very rapidly. It was evident that the presence of the fungus had much to do with this, for it was noted in many fields that the appearance and increase in abundance of this fungus were coincident with the sharp decline in thrips abundance.

During the season of 1933 the fungus was observed to be present over approximately the same area but was not as abundant, and did not cause such a reduction in the numbers of thrips as was noted during the previous season, undoubtedly because prevailing weather conditions were adverse during midsummer.

The fungus was again abundant in 1934 and very generally distributed throughout the Valley. Unfavorable weather conditions did not allow it to develop as early or as rapidly as in 1932 so that its presence did not coincide as accurately with the peak of thrips abundance. It is worthy of note that in the season of 1932, when the disease was present in greatest abundance, large numbers of lady beetles were found present in the fields. These may have served to distribute the fungus since several observers have noted that a large part of the food of certain lady beetles consists of fungus spores.

Value of Insecticides in Thrips Control

On the onions, thrips tend to congregate in the narrow space deep in the axils of the inner leaves, the so-called "chits". Fully 80 to 90 per cent of the thrips on a plant are usually clustered there. This habit presents one of the most baffling problems in thrips control and largely explains the comparative failure thus far of dusts (nicotine, cyanide, pyrethrum or rotenone) to control this pest. Insecticides applied as a spray, however, have proved more successful.

The peculiar type of leaf and its smooth waxy surface make the onion a difficult plant to cover thoroughly. Any spray to be effective must possess superior adhesive and spreading qualities as well as a satisfactory killing action on the insects.

In general, the various oil sprays proved very toxic to the thrips, but showed a great tendency to form into drops and roll off the leaves, resulting in uneven coverage. This allowed many insects to be untouched by the spray and so escape.

Nicotine sprays alone did not have the necessary physical qualities. The addition of soaps improved the adhesive and spreading qualities, and this combined spray has proved very successful. It showed excellent spreading and flowing qualities and allowed a thorough and uniform coverage of the smooth, waxy surface of the onion plants. Practically all of the run-off flowed down to the base of the leaves. When the spray was applied at 175 to 200 pounds pressure it readily penetrated the "chits", thus reaching the parts of the plant where thrips would be principally located. (Fig. 8.) The alkali of the soap also served as an activator of the nicotine.

This nicotine–soap combination has been tested over a period of years involving different weather conditions and various types of fields and degrees of infestation. The results have been so uniformly successful that this spray has been used as a standard by which to measure the efficiency of other insecticides. In field tests in a large commercial planting at North Sunderland, one application of this combination cut down the thrips population from an average of 5230 per 100 plants to 125, representing over 97 per cent control. In the experimental plots this spray has reduced light infestations of 1200 thrips per 100 plants to 125; and heavy attacks varying from 3000 to 5000 thrips per 100 plants before spraying to 125 to 190 following the application.

Thorough spraying to insure complete coverage of the plants usually reduced the average number of thrips per plant to 1 or 2 specimens. A detailed examination of a field the day after the application showed the following distribution of thrips.

Percentage of plants	No. of thrips per plant
80	0
2	15
12	10
6	5

Previous to the application 94 per cent of the plants were infested, 33 per cent showing an average of 30 to 50 thrips per plant.

Of the various activators and spreading agents, Penetrol and a commercial flowable pine tar soap have proved the most promising. Penetrol increased the action of the nicotine but did not show as good spreading qualities as did fish oil soap. The pine tar soap, however, gave excellent spreading and wetting qualities and, as far as could be measured, furnished as effective a combination with nicotine sulfate as fish oil soap.

Of the other materials tested, none has proved as effective as nicotine sulfate although many have shown promise. At present prices none of these, however, offers any material reduction in cost over nicotine sulfate.

The combinations of molasses with either Paris green or lead arsenate which have been so effective against gladiolus thrips caused considerable burn to onion plants after each application.

Plots treated with naphthalene flakes showed comparatively slight damage from thrips and this treatment appears to have promise. The material DAO, a dry powder broadcasted along the rows, checked thrips somewhat but proved too expensive for large areas. It also showed a tendency to burn the plants.

Derrisol, a rotenone compound, proved somewhat slower in its initial effects but showed a residual effect over an extended period so that reinfestation was retarded.

Ku-ba-tox, a rotenone compound, applied as a spray proved nearly as effective as nicotine sulfate although not as rapid in its action. Like Derrisol it showed considerable residual effect and consequently furnished protection over a period of several days.

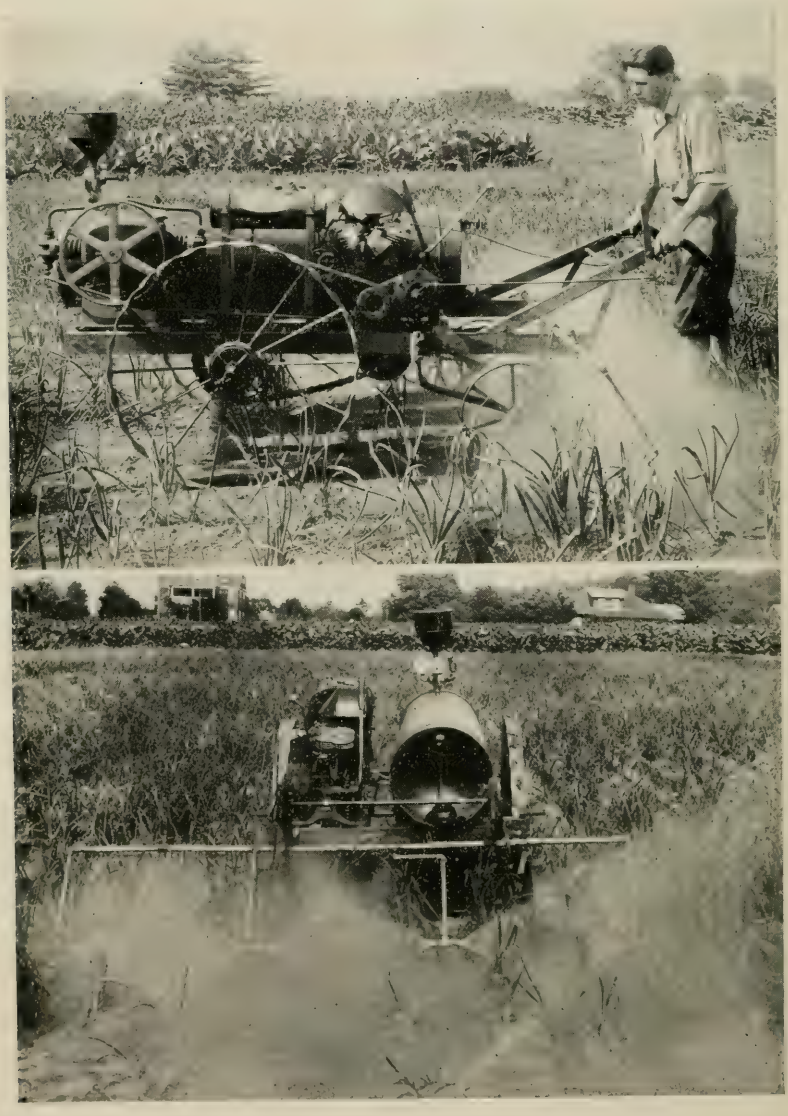


Figure 8. Spray machinery adapted for onion thrips control.

Spray Schedule for Thrips Control

At the height of the growing season, the rate of reproduction of thrips is high so that reinfestation of the onion plants is very rapid. Consequently a follow-up spray is practically essential. This should be applied as close as possible to the time when all the eggs have hatched and before the first larvae to appear have reached maturity and left the plants for the nymph stage. Life history studies have shown that in the Connecticut Valley region the duration of the egg stage averaged 5 to 6 days, while the larvae required about 7 days for full development. It would appear, therefore, that the second spray should follow 5 to 6 days after the first. In view of the residual effect of many of the above sprays the period between applications, therefore, could be safely extended to 7 or 8 days.

If the attack is very severe, reinfestation either by young newly-hatched larvae or by thrips migrating from neighboring fields (particularly sets) may make one or more later sprays necessary. After the first week of August, the plants have usually reached a size and stage of development where they can successfully withstand an ordinary attack, as do set onions earlier in the season, so that further spraying is unnecessary.

SUMMARY

Experiments were conducted on alluvial soil typical of most of the soils on which onions are grown in the Connecticut Valley. In the experiments with fertilizers, five crops were grown from seed and three from sets. The principal results and conclusions were:

1. Starting with a soil having an initial pH value of 5.3, marked increases in yields of onions were obtained by liming. Two tons of ground limestone, given in two applications of 1 ton each, caused an average increase in three years of 35 per cent. In the year immediately following the application of the second ton, increases in yield varied from 70 to over 100 per cent. On this soil 3 tons of ground limestone gave almost as large yields as higher quantities in initial application. Onions grew well in a slightly acid soil, and the optimum reaction appears to be between pH 6.0 and 6.5. A desirable practice seems to be to bring the soil to the optimum range of reaction by one or two applications of lime, and then maintain it there by frequent small applications, say 1 or 1½ tons every 2 or 3 years.

2. In a test of several grades of fertilizer in which the ratio of nitrogen, phosphorus, and potassium varied, greatest response was obtained from an increase of phosphorus, but significant increases were obtained only when potassium was increased also. No significant increases were obtained by raising the percentage of nitrogen from 4 to 6 when all was applied before seeding; but when the extra nitrogen was applied later in the growing season as a side dressing, increases resulted with onions grown from seed, but not with those grown from sets. In this experiment onions did best with a 4-12-8 mixture applied at the rate of 2500 pounds per acre. For the Connecticut Valley a mixture of approximately this ratio is recommended, although a little higher percentage of nitrogen may be better for the average Valley soil.

3. It was found that a 4-12-8 mixture carrying one-half its nitrogen in organic form gave better results with onions grown from seed than did another of the

same grade but containing inorganic nitrogen only. Only a slight advantage, if any, appeared in this respect with onions grown from sets. These results seem to be closely related to the length of the growing season of the two types of onions.

4. Deferring application of one-third of the nitrogen until the tops were about three-fourths developed gave erratic, but on the whole beneficial results with seed onions. Set onions were not benefited. Rainfall and temperature during the growing season, as well as the length of the growing season, appear to have been important factors in this experiment.

5. A double-strength mixture (8-16-8) proved as satisfactory as the standard single strength 4-8-4. Ordinarily high-analysis mixtures are more economical than low- or medium-analysis mixtures.

6. Muriate of potash proved fully as satisfactory as the sulfate, as a carrier of potash for onions, so far as yield is concerned. The muriate is usually cheaper than the sulfate per unit of potash.

In experiments with cover crops, it was found that certain grass and clover crops could be grown by seeding them in onions about the last week of July, but no particular benefit was derived from them. Difficulties were encountered in curing the onions with the cover crops present. For the purpose of checking losses of plant food, reducing water and wind erosion (dust storms), and increasing organic matter in the soil, cover crops in onions may have their place. Against slight possible advantages, however, must be weighed the cost of seed and extra labor in curing. It is believed that cover crops may be more successful with set than with seed onions because of the early maturity and removal of the set onions from the field.

In experiments in spacing and rate of seeding, onions were seeded at the rates of 3.5, 4.5, and 6.85 pounds per acre, with rows 13, 15, and 18 inches apart. The heavier rates of seeding gave larger yields, but a higher percentage of small bulbs. The greater distances between the rows slightly increased the percentage of large bulbs, but the total area was not used so advantageously with the 15- and 18-inch distances as with the 13-inch distance. The rather common practice of 4 to 5 pounds of seed per acre with rows 13 inches apart appears to be satisfactory, if not the best, for the Connecticut Valley.

Experiments in the effect of the size of the set on yield and quality of the crop gave the following results:

1. Onion sets below ¾ inch in diameter developed a very small percentage of seed stalks. Sets larger than ¾ inch developed such a high percentage of seed stalks that the resulting crop was of poor quality.

2. Removing the seed heads by breaking them off as they appeared did not significantly affect the number of seed stalks or divided bulbs, but did increase the weight of bulbs and the total yield. The practice of removing seed heads is recommended when large sets are planted.

3. Greater yields were obtained from large sets (¾ to 1 inch) than from smaller sizes, but on account of the high percentage of onions with seed stalks and divided bulbs, the quality of the crop was much poorer. Even though a greater yield may be obtained, and in a shorter time, from large sets, a greater net income

may be expected from the medium size sets (½ to ¾ inch), because the crop will be more uniform and of better quality, and because the initial outlay for sets is less on account of the smaller number of bushels required for planting. Sets smaller than ½ inch are too small for best results.

4. A comparison was made between sets graded from ½ to ¾ inch and those from 3/8 to 7/8 inch. The yields of marketable bulbs were practically the same from the two size groups, but there were more seed stalks, divided bulbs, and small onions from the 3/8- to 7/8-inch group. The difference in price of the two grades of sets would largely determine which to use.

Experiments were conducted with methods of growing onion sets. The results show that very good yields of sets of high quality may be obtained, that they can be kept in storage without excessive loss from decay, sprouting, or shrinkage, and that when planted they will produce satisfactory onions. From the experiments it seems that about 50 pounds of seed to the acre drilled in a row about 2 inches wide, and fertilized with 500 to 1000 pounds of a good onion fertilizer, will give good results. Careful judgment must be exercised in regard to the proper time of pulling the sets.

Selection and breeding of onions and the testing of varieties have been carried on for the past ten years, in an attempt to find or produce varieties more suitable to the Connecticut Valley than those now grown. Several strains have been inbred for five generations, and some crosses have been made, but no strains of commercial importance have been developed. In this work good results were obtained by transplanting to the field young onions started in the greenhouse, and this method is thought to have possibilities as a practical cultural method in the Connecticut Valley.

A short summary is included of previous work with some of the most important of the diseases attacking onions in this region, together with recommendations for treatment.

Experiments with the control of onion thrips have shown the following:

1. Set onions are a favorite breeding place for thrips, which migrate to near-by fields of seed onions when the set onions are harvested. Seed onions grown at a distance from set onions showed a much less severe infestation.

2. In a study of different types of onions, it was found that those with upright growth and an open chit were more resistant to the attack of thrips than those not showing these characteristics.

3. A fungus disease which is prevalent in some years helps to keep the thrips in check. It is not a reliable control, however, since its presence seems to be largely dependent upon the weather.

4. A nicotine-soap spray has been tested over a period of years, under different weather conditions and with various degrees of infestation, and has proved uniformly successful in controlling thrips. At the height of the growing season, reinfestation of the plants is very rapid and a follow-up spray is necessary, five or six days after the first application.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
3M-6-'35. No. 4807

319

VIRGINIA POLYTECHNIC
AGRICULTURAL DIVISION LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 319 MARCH 1935

A Study of Variation of Salmonella Pullorum

By H. Van Roekel

Bacterial variation has played an important role in bacteriology and related fields of science. From a practical point of view, and particularly in the diagnosis, control and eradication of human and animal diseases, it has presented problems of great importance. Since bacterial variation has received little attention in the study of pullorum disease, it was the purpose of this investigation to add to the knowledge on this subject.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

A STUDY OF VARIATION OF SALMONELLA PULLORUM[1]

By H. Van Roekel, Chief of Laboratory
Poultry Disease Control

INTRODUCTION

Bacterial variation has been observed in numerous species of microorganisms, according to Hadley, Löhnis and others. It is of interest to note that this phenomenon or group of phenomena was recognized by some of the early investigators in bacteriology, contrary to the generally accepted view that individual species maintain their morphological and other characteristics with great constancy.

Bacterial variation has received little attention in the study of pullorum disease. From the many reports that have been published since the isolation of the etiological agent by Rettger in 1899, we were until quite recently led to believe that the organism is very stable in its morphological, cultural, pathogenic, and serological properties. Variations in carbohydrate fermentations have been reported, but the differences have been attributable in most instances to such factors as culture media, incubation temperature, observation time, etc.

Epornitics due to *S. pullorum* have been found to occur in varying degrees of intensity, showing that the organism may fluctuate widely in pathogenicity. A most striking case may be cited in the fatal outbreak observed by Plastridge and Rettger (1930) among young and adult domestic fowl. In this instance the adult stock suffered rather heavy losses, which is, indeed, very uncommon in natural outbreaks. Further details of this outbreak will be discussed later.

Dearstyne, Kaupp, and Wilfong (1929) detected intermittent and low titre reacting birds, but the relation of such reactions to the infecting organism was not investigated.

The employment of the macroscopic agglutination test as a diagnostic means of detecting "carriers" of the causative organism has been and is recognized as a progressive step in the control and eradication of the disease. While the testing method has been improved and standardized to a high degree of efficiency, yet certain important and perplexing problems still remain to be solved. In the routine testing of flocks, doubtful or non-specific reacting birds may be encountered in small numbers in most flocks and in large numbers in occasional flocks. Whether or not this problem will prove to be an everpresent one appears dependent upon the insight that may be gained concerning the reagents and the factors involved in antibody production and the agglutination phenomenon. To what extent bacterial variation enters into this problem in nature is a question.

It has been recognized for several decades that suitable strains are necessary to produce a satisfactory antigen for the agglutination test. While attempts have been made to designate certain strains and methods as standard in order to overcome serological discrepancies and difficulties, certain problems still remain. This fact has been observed in the eradication of pullorum disease where the macroscopic agglutination test was employed. Further knowledge concerning bacterial variation of *S. pullorum* which will, in a measure at least, solve our present problems may be anticipated.

This investigation was stimulated by the fact that our present understanding with regard to variation of *S. pullorum* is, indeed, very limited, as has been shown by Mallman (1932). It was deemed advisable to determine to what extent variants of this organism occur in nature, as well as to what extent they may be present under certain laboratory conditions; and also to study some of the morphological, cultural, pathogenic, and serological properties of the variants, with the purpose of offering an explanation for problems encountered in our present diagnostic methods.

---

[1] This bulletin covers in part the work submitted to the Graduate School of Yale University as part requirement for the degree of Doctor of Philosophy. The writer desires to express his sincere thanks and appreciation to Professor Leo F. Rettger, Yale University, for his stimulating interest and constructive criticism during this investigation; to Mr. O. S. Flint for assisting in the photographic work; and to Doctor D. M. Yegian for technical assistance.

HISTORICAL REVIEW

The field of bacterial variation has attracted considerable interest and caused much controversy among investigators since the early days of bacteriology. Apparently two strongly opposing schools on the subject of variability and mutation existed. The one subscribed to the monomorphic view, while the other supported the pleomorphic concept that microorganisms are extremely variable in their characteristics, especially when subjected to changed external conditions. The monomorphists maintained that bacterial species preserve their morphological and other characters with great constancy, and that all deviations from the normal type are to be considered as contaminations or so-called involution forms.

Since the literature on all phases of variation, dissociation and mutation has been so voluminous, the reader is referred to the reviews published by Löhnis (1922), Hadley (1927) and Arkwright (1930). In the résumé of the literature cited here it is deemed advisable and expedient to present some of the outstanding observations of general interest, as well as those contributions which are related to the phases included in the problem under investigation.

The extreme views of Nägeli (1877) concerning variability are of interest. He believed that all species of bacteria are highly variable and capable of passing from one morphological state to another, as well as undergoing profound physiological changes. Furthermore, he claimed that one species can be the etiological agent in various forms of disease.

For a decade or so after the views of Nägeli were presented very little was published on the subject of variation.

Chamberlain and Roux (1883) observed that anthrax cultures became asporogenic when subjected to phenol and other antiseptics. This characteristic was retained even upon passage through guinea pigs, rabbits, and sheep. Later Roux (1890) reported that the virulence of the asporogenic type was reduced, but that it could be raised by passage through susceptible animals. In cultural and physiological properties this type resembled the sporogenic form. The author suggested that the loss and gain in virulence may occur under natural conditions, and that the so-called saprophytes may progressively adapt themselves to a parasitic mode of living.

Bacteria cultivated in the presence of small amounts of agglutinating serum were reported by Durham (1898) to exhibit departures from their normal habit of growth. Morphologically the organisms revealed a tendency to grow in chains or threads, which were normally absent.

Nicolle (1898) observed spontaneous clumping of broth cultures of *Bact. typhosum* to the extent that they were unsuitable for the agglutination test. The phenomenon was similar to that observed when the culture was placed in contact with immune serum. Cultures exhibiting spontaneous agglutination possessed slight sensitivity toward serum agglutination. Repeated inoculation into serum-broth medium failed to eliminate the property described.

Horton-Smith (1900) encountered considerable variation in the agglutinability of some typhoid strains. He found that a broth culture may manifest inagglutinability, while a suspension of the same strain prepared from an agar slant is agglutinable.

Spontaneous clumping was also observed among typhoid strains by Savage (1901), who emphasized the fact that this phenomenon may be of great practical importance, since it may lead to errors of diagnosis in routine work. An investigation of the conditions necessary for the formation of these clumps revealed that the phenomenon occurred within 24 hours, independent of age of cultures and of scum formation. Organisms suspended in saline solution, peptone-water, and broth exhibited clumping only in the broth.

Preisz (1904) found that *B. anthracis*, when cultivated on slightly alkalinized agar, developed papillae or secondary colonies, which appeared as contaminants, and after several weeks might give rise to tertiary colonies. Marked differences in the morphology of the bacilli belonging to the primary and secondary colonies were observed.

Hiss (1904) observed that *Bact. dysenteriae* (type "Y"), when subjected to frequent transfer in maltose medium, acquired the property of attacking that carbohydrate more rapidly.

Steinhardt (1904) was able to demonstrate the influence of serum on the virulence of paradysentery and typhoid organisms. Normal horse serum exhibited little influence, while inactive and immune sera reduced the virulence. He isolated a spontaneously agglutinating strain from a typhoid stock culture. The colonies of the agglutinating type possessed a more irregular surface and greater opacity than the stable strain.

Eisenberg (1906) observed granulation formation in typhoid and other colonies after the addition of egg albumin to the medium. This appearance was obtained only in old cultures. He believed that this type of development was due to the detachment from the colonies of bacilli which penetrated more deeply into the medium and gave rise to small adjacent colonies.

The investigation of Massini (1907) definitely revealed that a lactose-fermenting organism was derived from a non-lactose-fermenting strain, and that it was absolutely stable. On lactose-fuchsin agar it formed white colonies, but after a short incubation period red papillae developed. This occurred only in the presence of lactose, and the new characters could be removed by subjecting the organism to phenol medium. An homologous antiserum for the white strain agglutinated both the white and red strains to the same degree. Likewise, an antiserum prepared against the red organism agglutinated both types. Histological sections of the papillated colonies revealed light and dark streaks which extended throughout the colony mass. Certain layers in the colony stained with different intensities.

Peckham (1907) was successful in accentuating the proteolytic activity of the typical colon bacillus, and in stimulating indol formation by atypical colon organisms that had been devoid of it, and by typical typhoid bacilli. He also stated that *Bact. coli-communis* at times possesses pathogenic properties, and that by artificial methods of treatment it may often be brought from a condition of benignity to one of virulence.

Twort (1907) was able to induce *Bact. typhosum* to ferment dulcitol and lactose by cultivating the organism in the respective media and transferring at biweekly intervals over a long period of time. Likewise, *Bact. paratyphosum B* acquired the power of fermenting saccharose. He concluded that by this means a pathogenic organism may be altered until it gives fermentative reactions characteristic of a non-pathogenic member of its group. Furthermore, he suggested that this process may occur in nature.

Goodman (1908), by artificial selection, obtained a strain of *C. diphtheriae* which had moderate power of producing acid in dextrose broth, and two strains possessing respectively a greatly augmented and greatly diminished power of acid production. He suggested that fermentative properties are not species characters, since the zymogenic power exhibited can be readily and markedly altered at will by artificial selection.

Buchanan and Truax (1910) attempted to select high and low acid races of *Strept. lacticus*, but found no evidence of a divergence of high and low races among the cultures studied. They concluded that impressed variations did not appear to be heritable and that continued growth of *Strept. lacticus* under favorable conditions, seemed to render the organism less variable.

Jacobsen (1910) isolated a typhoid strain which he designated typhoid mutabile, since it was characterized by a restricted colony type possessing slight agglutinability and yielding secondary colonies which resembled typical typhoid in morphology and serological behavior.

Burri (1910) encountered an organism belonging to the coli-typhoid group which he designated *Bact. imperfectum*, since it was unable to ferment saccharose, but, when cultivated in the presence of this carbohydrate, certain colonies acquired this property. The latter he named *Bact. perfectum.* Since the ability to ferment saccharose was acquired gradually, he concluded that this property appeared to be latent in the *imperfectum* type.

Typhoid strains could be trained to attack dulcitol, according to Penfold (1911). Non-fermenting colonies on dulcitol agar plates revealed after five days or more secondary colonies as papillae which might or might not possess an acid reaction. He further observed that *Bact. typhosum* could be trained to ferment lactose only with very great difficulty, and that the newly acquired property was very unstable and transient. He concluded that papillae formation indicates that variation affects only very few individuals of a colony to a great extent, and does not guarantee permanency in the character.

Rettger and Sherrick (1911) stated that bacterial variation may be brought about by artificial selection. They maintained that variation does not depend solely upon changes in nutriment, environmental conditions, etc., but that it is frequently brought about through inherent properties within the organism itself. By artificial selection they obtained from a slightly pigmented strain of *B. prodigiosus* two strains showing in one case brilliant coloration and in the other complete absence of color. Also, they observed the return of the pigment-producing property in a strain of *Ps. pyocyanea* which had previously been very nearly colorless.

Müller (1911), working with typhoid and known pseudo-dysentery bacteria, observed secondary colonies when growing these organisms on rhamnose agar. He regarded this as a new characteristic comparable to that of *Bacterium coli mutabile*, and further observed the same forms on old gelatin cultures of typhoid.

Dobell (1912) concluded that bacteria are subject to mutation in that a given race may give rise to a new race which differs from the parent strain in its genetic make-up. The new characters of the race may be transmitted for many generations.

Revis (1912) subjected a typical strain of *Bact. coli* to peptone broth which contained malachite green. Subsequent culture on ordinary agar yielded large, viscous, circular masses, which consisted of a mixture of very long filaments and short bacilli, together with a gummy cementing substance. He found this strain to differ physiologically, morphologically and culturally from the typical *Bact. coli.*

A temporary alteration in cultural and antigenic properties of *Staphylococcus aureus* was demonstrated by Abbot (1912). Pigment formation and proteolytic action were increased, while the agglutinability was decreased. No modification was observed in its pathogenicity, carbohydrate-splitting power and ability to clot milk.

Baerthlein (1912) isolated several coli-like organisms from the intestinal tract which appeared colorless on Endo-agar, but formed red secondary colonies. These mutants gave rise to further mutants which were characterized by their colonial, cellular, and serological differences. Two colony types were detected: the one a transparent type containing long, slender filaments, and the other opaque containing short, plump bacilli. The opaque type appeared to be antigenic but inagglutinable with homologous and heterologous antisera.

From studies on strains isolated from excreta of suspected typhoid carriers Penfold (1912) concluded that lactose mutation appears to be a common property of many bacterial species, and that it has no specific differentiating value. The power to vary quickly in respect to dulcitol fermentation appears to belong to every strain of *Bact. typhosum*. Furthermore, the inability to vary quickly in respect to certain carbohydrates would appear to be as characteristic of certain species as the power to vary.

Eisenberg (1912) observed numerous colonial and cellular types in his study of the cholera vibrio.

Rowland (1914) also demonstrated variation in cellular forms of the plague bacillus. He further observed that the virulence and immunizing power of this organism can be greatly modified when cultivated in various culture media.

Cole and Wright (1916) concluded that most of the variation observed in ordinary cultures is due to selection of pre-existent biotypes by the investigator or by the environment. Certain biotypes may be entirely lost if the process of selection is complete, and the culture will not return to the original type, even when placed again under normal conditions. If the selection process is incomplete, certain biotypes become predominant and others become suppressed, so that the return to normal conditions brings out the dormant types adapted to those conditions, and the culture reveals its original characteristics.

In 1917 Jordan made a comparative study of biochemical and agglutinative properties of some members of the *Salmonella* group. He offered the following conclusion: "Old stock cultures that have been in laboratory collections for some years often show variations, irregularities, and departures from type. Some give reactions, biochemical and agglutinative, that they did not give when first isolated. On the other hand, some strains that apparently possessed unusual fermentative reactions when first isolated later show conformity to type".

Eisenberg (1918), in one of his series of papers on variation reported a large number of strains in the coli-paratyphoid-dysentery group. He observed variation in size, transparency and structure of colony, mucoid property, biochemical activity, gelatin liquefaction, pigment production, and reducing power. The coli-mutabile strains possessed the power to change suddenly. Dwarf colonies were detected among typhoid, paratyphoid B, and dysentery strains, as well as secondary colonies among the latter.

A classical work on variation appeared in 1918 by Baerthlein, which included an extensive study of colony variation and other characteristics in fourteen bacterial species. He demonstrated numerous colony types and correlated other important characteristics, such as cell morphology, slime and pigment production, biochemical and serological reactions, and virulence. His observations greatly added to the knowledge of bacterial variation.

An inagglutinable strain of the Shiga dysentery bacillus was experimentally produced by Benians (1919) from an agglutinable strain, by subcutaneous inoculation into a guinea pig of the agglutinable bacteria suspended in mucilage of tragacanth.

Dawson (1919) in an extensive study of bacterial variation induced by changes in the composition of culture media observed that constituents in the medium stimulated variation from the simplest to the most complex degree, which in some cases practically amounted to the production of a new strain.

Mackie (1920) reported variants obtained from *B. vesiculosis* when growing the original type on brilliant green agar. The variants exhibited differences in colonial and cellular morphology and in agglutinating ability. One variant strain possessed a higher degree of agglutinability than its parent strain.

Arkwright in 1920 introduced the terms "S" and "R" to designate so-called "smooth" and "rough" colonies. He obtained from a single strain two forms, one a "smooth" which formed a stable suspension in physiological saline, and the other a "rough" which agglutinated in saline solution without the addition of serum. These forms were derived from *Bact. dysenteriae* (Shiga), *Bact. typhosum, Bact. paratyphosum B*, and *Bact. dysenteriae* (Flexner). Other distinguishing characteristics, such as behavior in broth, and antigenic and agglutinative properties, were ascribed to the two forms. In 1921 Arkwright further reported that "S" and "R" forms, as well as intermediate forms of *Bact. dysenteriae* (Shiga) proved to be virulent for rabbits. It was further stated that to change one form into the other, after they were apparently quite pure, was more difficult than when unselected cultures were used which had shown "S" and "R" characters.

In 1921 De Kruif reported two types of organisms as existing in a culture of *Past. lepiseptica*, recently isolated from a spontaneous infection. The two organisms differed greatly in their degree of virulence, as well as in other characteristics. The features of each type were constant through many passages in artificial media.

Non-specificity of agglutination with "rough" variants was reported by Schütze in 1921. He defined a substrain variant as one which contained less agglutinating antigen than another of the same type. It absorbed and agglutinated the serum of a superstrain, but not to the extent that the homologous strain did. On the other hand, the superstrain agglutinated and absorbed the serum of the substrain to its titre limit. The author also referred to "serological cosmopolitanism" among rough cultures, which signified that two rough members derived from unrelated sources possessed serological relationships.

In 1922 Löhnis presented an extensive review and discussion on the subject of variation and life cycles of bacteria, with special reference to the different phases in the life history of microorganisms. He maintained that all the bacteria studied live alternately in an organized and in an amorphous or symplastic stage, and that the life cycle of each species is composed of several subcycles showing wide morphological and physiological differences.

Arkwright (1924) observed that variants sensitive to bacteriophage arose spontaneously in old normal cultures from resistant strains; also, that sensitive variants which were studied had always been "rough", that is, were agglutinated by salt (0.85%). However, not all "rough" variants had been sensitive to phage action, although all of the "smooth" cultures examined were resistant to phage. The variants obtained by phage action and without the addition of phage were very similar.

In 1924 Arkwright and Goyle attempted to determine whether the "S" and "R" forms correspond in any way to the "O" and "H" forms of Weil and Felix. The analogies that the authors have advanced do not appear justified from the standpoint of the organism and tests employed.

Savage and White (1925) stated that in direct platings from pathological material, colonies of *Salmonella* bacilli and other intestinal pathogens were, as a rule, wholly smooth. Occasionally, however, roughness might be detected in the primary cultures. They demonstrated in a few experiments that "rough" forms possess a lower pathogenic and invasive power than the smooth type. Also, they inferred that in nature a process of natural selection tending to smoothness doubtless occurs, but that this presumably consists in the weeding out of "rough" variants which may have low pathogenicity and penetrating power. They suggested maintaining smooth cultures either by animal passage or by using unheated culture medium.

In 1925 Enderlein described in great detail the phenomenon of cyclogeny. He defined cyclogeny of bacteria as a cycle of morphological development commencing with the simplest morphological unit, "mychit", passing through the highest morphological structure, and then returning to the "mychit" stage. The different stages of morphological structure were designated as cyclostages, and a single passage through a cyclogenic development process was called a cyclode, which had a peak in its development that was designated as "Kulmination". Virulence and pathogenicity were associated with the parasitic cyclostage, which was the virostage.

Jordan (1926) demonstrated that single cell strains of paratyphoid bacilli of the "R" and "S" types could more or less regularly be made to yield cells of the opposite type by appropriate treatment.

White (1926) called attention to the effect of alcohol on rough variants. Rough forms were extracted with 96 per cent alcohol, which conferred upon the most salt-sensitive strains a degree of suspension stability at least equal to that of the normal smooth races. Among the 21 rough strains examined in the various *Salmonella* types, he did not encounter an exception or partial exception to this rule. Agglutination tests were performed satisfactorily with 0.85 per cent NaCl, and even at twice this concentration.

In 1927 Webster and Pritchett reported that smooth colony types of paratyphoid-enteritidis bacilli prevailed throughout the various stages of rodent typhoid infection. In the same year Webster and Burn reported the effects of external conditions in the occurrence of smooth, mucoid, and rough colony types in *Bact. enteritidis*.

Goyle (1927) was successful in deriving two forms (N and R) from *Bact. typhosum* and *Bact. enteritidis* by plating old broth cultures. The colonies of the "R" form differed from those of the "N" form in being larger and in having a surface which was markedly granular. An "S" form was obtained by growing the "N" type on phenol-agar, but it did not remain as a permanent variant. He observed that the "N", "S", and "R" forms differed in their antigenic, absorbing, and agglutinating properties.

In 1927 Arkwright reported that variants may be distinguished by a great variety of characters, some of which vary quite independently, while others are closely linked or correlated. Virulence of a culture and its value as a prophylactic agent may often be foretold, without animal inoculation, from purely cultural or cultural and serological features. He found that vaccines prepared from "R" forms gave comparatively slight protection, while "S" forms made efficient vaccines.

In 1927 Gwatkin reported the isolation of a weak pullorum phage from an abscess in a rabbit inoculated with *Bact. pullorum*. Pullorum cultures placed in contact with this phage yielded two types of colonies. The individual bacteria in one type of colony were coccus-like and were not agglutinated by pullorum serum, but gave the same fermentation reactions as the normal type.

It was observed by White (1928) that rough organisms which were agglutinated in the presence of NaCl (0.85%), were inagglutinable in the presence of the same salt concentration after being extracted with alcohol and chloroform. However, if the rough suspension was heated to 100°C. after treatment with alcohol and chloroform, it was again rendered unstable in saline (0.85%). Smooth strains treated in the same manner remained unchanged. The author concluded that the reaction of denatured rough protein to electrolytes afforded a final test for roughness. It was further observed that the most salt-sensitive races were by no means of necessity those which were the most serum-sensitive. It was suggested that the serum-sensitive reaction was due to a special substance or group of substances which appeared to be restricted to certain strains or types. The relation to normal agglutinins was also brought out. The isolation ot a soluble specific substance from the smooth races and not the rough was recorded. He regarded the soluble specific substance as the specific element of the smooth body complex of the *Salmonellas.* Circumstantial evidence pointed to a relation between soluble specific substance and salt-sensitiveness manifested by certain strains.

In variation studies with *B. subtilis*, Soule (1928) found that normal rabbit serum enhanced variation of this organism, while serum homologous to the variant stimulated reversion to the normal type.

Wilson (1928) reported that daily subculture in broth of *Bact. aertrycke*, (Mutton type), led in about four weeks to a marked change in the composition of the culture, the great majority of the virulent organisms present at the start being replaced by completely avirulent ones.

Lancefield and Todd (1928) showed that rabbit sera prepared against "Matt" hemolytic streptococci, whether virulent or avirulent for mice, contained type-specific antibody, while sera prepared against completely degraded glossy organisms contained no type-specific antibody.

Two serologically active protein substances and another that was non-protein were isolated by Furth and Landsteiner (1928) from *Bact. typhosum.* Cross-testing of non-protein substances of various species with the corresponding sera revealed a strong group reaction between *Bact. typhosum* and *Bact. enteritidis.*

Li (1929) reported that "S" forms of the hog cholera bacillus were virulent, while the "R" forms were not. Certain types of variants remained unchanged by serial animal passage. Successful results were obtained in attempting to produce a definite immunity against the virulent "S" forms with the living "R" forms.

Koser and Styron (1930) demonstrated that smooth forms of *Bacterium dysenteriae*, Sonne, could be formed from rough forms quite regularly by rapid, successive transfers in dextrose broth incubated at 37°C. In some cases the reversion appeared to be complete, and the rough forms totally disappeared. Rough cultures held on agar slants at room temperature were much more stable than when subjected to daily transfers on the same medium. A tendency toward spontaneous clumping in 0.85 per cent saline solution was observed in the relatively smooth cultures derived from the rough forms.

In 1930 Plastridge and Rettger reported a most unusual outbreak of pullorum disease. The nature of this outbreak appeared to be an acute septicemia among chicks and mature fowls which manifested marked pathological changes and suffered a heavy mortality. The causative organism isolated from the infected birds presented characteristics which had not been reported for *S. pullorum.* It failed to grow on nutrient agar containing meat extract, and grew indifferently on meat infusion agar. On pneumo-agar the organism developed reasonably well, while abundant growth was observed on liver infusion agar. Two types of colonies were observed on pneumo-agar which did not lend themselves to further propagation by transfer, except in one or two instances. The organism exhibited marked pleomorphism. The pleomorphic forms did not stain uniformly, and in some cases the violet color was retained in the Gram stain. Small cells resembling typical *S. pullorum* were observed among the larger pleomorphic forms. Visibly infected birds tested with known pullorum antigen possessed a high agglutinating titre. The organism recovered from these birds was agglutinable, and capable of attacking the same fermentable substances as *S. pullorum.*

White (1932) stated that, in addition to the carbohydrate haptenes which characterize the "S" and "R" forms of *Salmonella* bacilli, an alcohol-soluble protein which he termed "Q" was concerned in the somatic serology of these organisms. This substance was readily extracted by warm acid-alcohol and was a full antigen which stimulated the development of potent precipitating antibodies. It occurred in all of the serological types and variant forms of the *Salmonella* group. Besides the ordinary "S" and "R" forms of *Salmonella,* he referred to rough races derived from strains long cultured in the laboratory, which lacked the "S" and "R" carbohydrate haptenes, and in which no corresponding constituent had yet been demonstrated. These races he designated "p"- forms which agglutinated much more vigorously than did ordinary "R"-forms. The removal of the "Q" fraction markedly reduced the somatic agglutinability of the treated bacilli.

In 1932 Mallmann reported on dissociation of *S. pullorum* and related species. His studies were entirely confined to old stock cultures of *S. pullorum.* He classified his strains according to colony form into three groups: smooth, intermediate, and rough. Other colony types, such as mucoid and opaque, were completely ignored. In the investigation he observed two types of variation, the one involving the intermediate form, and the other the smooth and rough forms. The intermediate type was found to fluctuate in the direction of either "S" or "R" or both when subjected to different environments, but when the incitants were removed they would return to the intermediate type. In the study of the second type of variation, rough and smooth immune serum broth was seeded with rough and smooth strains, respectively, and incubated at optimum temperatures. Only temporary changes in colony forms were observed. Smooth cultures were changed to partially rough types by exposing them to bacteriophage, and rough types were converted to partially rough types by animal passage. When cultures were maintained in stock on liver infusion agar or gelatin-agar, the various strains tended to return to their normal type. Intermediate strains varied at times from one type to another. Liver infusion agar frequently caused stable smooth types to appear as rough types, but the condition was regarded as purely transitory. Electrophoretic measurements failed to show any significant changes due to animal passage.

Plastridge and Rettger (1932) reported different colony types of *S. pullorum* observed on various agar media. Meat and liver infusion agars produced more pronounced rough types than plain meat extract agar. Pleomorphic cellular forms, varying greatly in size, were encountered. Phage-treated strains yielded various colonial and cellular types. The phage action in some instances markedly affected the agglutinating properties of *S. pullorum.* A bacteriophage that was highly active against *S. pullorum* cells was obtained in extracts of livers and intestinal contents of adult birds surviving an acute attack of the disease.

White (1933) reported the isolation of a "T" substance from *Salmonella* bacilli by means of an extracting fluid containing 75 per cent alcohol, sodium chloride, and hydrochloric acid. This fraction, protein in nature, was extracted from "S", "R", and "p" races of several *Salmonella* types. It was concluded that the "T" fraction was more deeply situated in the organism than were the "S", "R", and "p" receptors, and could engage with its universal antibody only when the bacterial surface had been partly cleared of impediments as a result of washing, or during autolysis.

Henry (1933) observed that the "R" forms of *Br. abortus* exhibited less invasive power for the natural host than the "S" type. This relation likewise was true for agglutinogenic properties. Cultural examination of milk from reacting cows in various stages of lactation revealed no "R" types.

MacKenzie and Fitzgerald (1933) demonstrated qualitative and quantitative alterations in agglutinative, absorptive, and agglutinogenic properties of *Salmonella* and *Shigella* strains. The antigenic behavior was found to vary independently of colonial morphology and mode of growth in fluid media. The convergence phenomenon was observed in which variants, derived from different species, manifested serological identity.

Rettger and Gillespie (1933) found that cellular morphology varied with the medium employed and with the temperature and duration of incubation, in working with *B. megatherium*.

Stearn and Stearn (1933) in a series of papers referred to the fact that different H-ion concentrations may cause various types of growth with the same organism.

Murphy[2] in an attempt to induce variation in *S. pullorum* strains, observed that the variants failed to remain stable and that reversion to the so-called "normal" occurred on subsequent transfers.

In a recent paper by Plastridge and Rettger (1934) virulence studies on *S. pullorum* were reported. The strains employed were variants isolated from natural outbreaks or derived in the laboratory. The test animals included chicks, adult hens, rabbits and guinea pigs. Marked differences were observed in the virulence of the individual strains of *S. pullorum* for these animals. Some strains were found to be highly virulent for both chicks and adults; others possessed a low degree of pathogenicity for chicks, but were highly virulent for adult birds. Some strains were relatively avirulent for both young and adult chickens. Pronounced changes in virulence of some strains of *S. pullorum* were induced by the action of bacteriophage. The passage of strains through the animals had, in general, no appreciable effect on morphological, colonial, and agglutinative characteristics of the variants studied.

THE INCIDENCE OF VARIANTS AMONG NEWLY ISOLATED STRAINS

In the identification of *S. pullorum* strains several properties such as colonial and cellular morphology, Gram stain reaction, biochemical reactions, and serological response are studied. While this organism possesses certain features in common with some of the other members of the *Salmonella* group, yet as a rule it can be isolated and differentiated with ease. Associated with its cultural habits is a considerable tolerance to fluctuation in environmental conditions without leading to death of the microorganism. In spite of the fact that *S. pullorum* is not as selective in its growth environment as some organisms, certain conditions may bring about profound changes in one or more of its characters, as will be discussed later.

---

[2] Unpublished data (1933).

In order to detect variants among any strain of bacteria, it is necessary to establish a criterion for a so-called "normal" or typical strain. Rettger (1900) first described the organism as a Gram-negative, actively motile, non-liquefying, non-chromogenic, facultatively anaerobic bacillus with slightly rounded ends. When grown on agar the bacilli vary in size from 0.3—0.5 micron in breadth and from one to two microns in length. On agar plates the colonies are small (one-fifth of a millimeter) and white after twenty-four hours of incubation, but they may attain a diameter of one millimeter after several days of incubation. The colonies vary in form from oval, kidney-shaped, or even spindle-shaped, to round. In almost every case the colony surface is marked by a peculiar rosette figure.

Rettger and Harvey in 1908, after a more extensive study of the disease, concluded that the organism is a long, slender bacillus (.3–.5 × 1–2.5 microns) with slightly rounded ends. It usually occurs single, chains of more than two bacilli being rarely found. It is Gram-negative and stains readily by the ordinary basic anilin dyes. It is non-motile, non-liquefying, non-chromogenic, non-sporogenic, and facultatively anaerobic. On agar plates the colonies appear white and small at the end of twenty-four hours. They increase in size slowly and seldom attain more than one millimeter in diameter, even after a few days incubation. Under the microscope they appear yellow and vary in shape from oval and spindle-shaped to round. A rosette surface is usually demonstrable. On slant agar the growth resembled that of the typhoid bacillus.

Rettger and Plastridge (1932) in their recent monograph on pullorum disease state that in heavily seeded meat extract slants or plates the colonies are discrete and appear more or less dewdrop-like. When isolated on meat infusion or liver infusion agar the growth is more luxuriant, with characteristics approaching those of the coli-typhi group. Rosette figures are usually present on the colony surface.

In the examination of primary isolations the author accepted the aforementioned characteristics as a criterion for normal or typical *S. pullorum*. However, among the strains investigated it was observed that certain characteristic features may be added to those described above. On plain meat extract agar (pH 7.0 — 7.2) heavily seeded with inoculum, the colonies appear discrete, smooth, glistening, homogeneous, entire, dome-shaped, transparent, and varying in form from round to angular. On chicken infusion agar the growth is slightly more luxuriant, with colonies possessing a lesser degree of transparency. On liver infusion agar the growth is even more luxuriant than on meat infusion medium. The colonies are smooth, round, entire, glistening, homogeneous, markedly translucent, and extremely dome-shaped. Congested colonies remain small (1 mm. or less), but isolated colonies may attain a diameter of three to four millimeters or more. Surface markings may appear as the colony increases in size and age, but as a rule the young colony on a heavily seeded plate changes little with age.

The cellular morphology of the organisms taken from growth on meat extract agar resembled closely the description cited above. In most smears an occasional filament and large cell was observed. Similar observations were made in smears prepared from growth on meat infusion agar. However, a most striking picture was noted in smears prepared from colonies on liver infusion agar. The cells were considerably larger, stained with different degrees of intensity, and varied quite markedly in their shapes. This cellular response will be discussed further in another section.

In the fermentative studies the following substances were employed to identify *S. pullorum:* dextrose, maltose, lactose, sucrose, and dulcitol. The production of acid and gas or acid only in dextrose was considered typical of the organism.

Antigens were prepared by removing the growth from young cultures with 0.9

per cent NaCl solution which contained 0.5 per cent phenol. These antigens were tested with negative and positive pullorum sera in dilutions of 1:10 and higher. The results of the test were recorded after 48 hours incubation.

All strains were stained by the Gram method.

The cultures were obtained from several different sources, including eggs, chicks, and mature birds. A large number of cultures was received from my associates in the Department of Veterinary Science. The original cultures received from Amherst were isolated on chicken meat infusion agar plates. The age of the culture at the time of the examination varied from three to seven days. In the majority of cases plain meat extract agar plates were streaked with the primary cultures, in order to determine the character of the growth on meat extract agar during the various incubation periods.

Primary isolations of *S. pullorum* from chicks and adult birds were also received from various members of the Yale Department of Bacteriology.

The Department of Veterinary Science also furnished fresh eggs laid by hens whose sera reacted with pullorum antigen. Among 176 eggs cultured, 39 yielded *S. pullorum*. As a matter of interest concerning the bacteriological examinations of the eggs, it may be stated that the percentage of isolation is markedly raised by increasing the incubation period from two to six days. No definite explanation is offered as to why the presence of the organism is not detected by streaking on agar plate with egg yolk-broth mixture which has been incubated only 48 hours. In every instance the eggs were incubated in the shell for a period of seven days before being cultured. It was also observed that occasionally eggs contain particles of necrotic tissue which have been picked up in the abdominal cavity by the oviduct and expelled as part of the egg. Such bodies may be found in the albuminous portion. By careful technique the yolk and the foreign body may be cultured separately. In such cases it was observed that the yolk may be sterile, while the necrotic tissue yields *S. pullorum*. Hence, it appears important, in the bacteriological examination of fresh eggs, to recognize the fact that the organism may exist in other portions of the egg aside from the yolk. Also this observation suggests that the disease may be transmitted from adult to chick by means of such infective foreign bodies, instead of the yolk in every instance, as is the common belief.

A total of 163 strains was examined as to colonial morphology, Gram stain reactions, carbohydrate fermentations, and agglutinability. During a period of approximately fourteen months, 69 strains were isolated from maturing and adult birds, 55 strains from chicks and 39 strains from fresh eggs. The organism was recovered from various organs, tissues and diseased processes.

Thirteen of the 163 strains did not resemble typical *S. pullorum* in every respect. Table 1 shows that the majority of these 13 strains were salt sensitive, exhibiting a tendency to settle out in normal NaCl solution.

In the original isolation the colonial and cellular morphology, carbohydrate reaction and Gram-staining properties resembled those of *S. pullorum*, except in two strains, 3 and 12. The latter exhibited a rough type of colony, but on subsequent transfers to meat extract agar and beef and liver infusion agar the growth was smooth and typical. No explanation is offered for this marked temporary roughness as manifested in the primary culture.

The different atypical strains were tested on several occasions with positive and negative pullorum sera. The results of a few of the tests are shown in Tables 2 and 3.

The antigens listed in Table 2 were prepared from meat extract agar cultures which had been incubated at 37° C. for 48 hours. The cells were suspended in

TABLE I. HISTORY OF THE NEWLY ISOLATED VARIANTS

Strain No.	Date Isolated	Source	Remarks
1	10/4/32	Hen (ovary)	Salt sensitive
2	11/21/32	Hen (ovary)	Salt sensitive
3	11/22/32	Pullet (liver)	Grew with some difficulty on plain agar, and in sugar media. Revealed a tendency to settle out in broth, colony outline irregular when small, filamentous forms numerous.
4	12/1/32	Hen (hematoma)	Salt sensitive
5	12/19/32	Hen (ovary)	Salt sensitive
6	2/3/33	Hen (peritoneum)	Salt sensitive
7	2/3/33	Hen (ovule)	Salt sensitive
8	5/26/33	Chick	Salt sensitive
9	10/20/33	Chick (spleen)	Salt sensitive
10	12/29/33	Chick (yolk)	Salt sensitive
11	1/7/34	Hen (ovule)	Salt sensitive
12	2/15/34	Hen	Rough colony on primary culture
13	11/24/33	Egg	Salt sensitive

0.9 per cent NaCl solution which contained 0.5 per cent phenol. In three instances the salt concentration was lowered to 0.22 per cent,in order to reduce the instability of the strain in saline solution. It had been observed previously that these three strains (9, 11, and 13) were salt sensitive. The concentration of the antigens was adjusted to the desired turbidity, which in the final serum-antigen mixture was equivalent to tube number 1.0 of McFarland's nephelometer scale. All strains produced a uniform, homogeneous turbidity, with the exception of No. 8, the suspensions of which appeared slightly clumpy.

The results in Table 2 show that the different strains do not behave alike as antigens in the presence of positive and negative sera and in 0.9 per cent saline solution. In the majority of the antigens it was difficult to determine whether the cells were agglutinated. Stable, well-defined clumps of cells were not visible to the naked eye, as one ordinarily observes in typical agglutination with *S. pullorum*. However, even with a so-called typical pullorum antigen, one may observe more than one type of agglutination. This fact is well brought to light when numerous agglutination tests are recorded in the routine testing of fowl sera. Arkwright (1930) stated that specific and non-specific agglutination of bacteria is a phenomenon governed by conditions which belong to the realm of colloidal physics and which are imperfectly understood at the present time. When old cultures containing autolyzed or fragmented bacterial cells are suspended in salt solution they may cause a precipitate. Under certain conditions the precipitating substance may entangle the bacterial bodies, producing a reaction that can not in reality be considered identical with true agglutination brought about by properly sensitized intact bacterial cells suspended in a suitable electrolyte solution. A comparable phenomenon is frequently observed when substances of a lipoid and protein nature are precipitated under certain conditions, bringing down the bacterial cells with the precipitating material.

According to the results tabulated in Table 2, it is apparent that certain factors are operating which are difficult to explain. The character of the agglutination or settling differed among certain antigens. Some antigens appeared unstable in 0.9 per cent saline solution, but in the presence of negative serum the cells remained in suspension. In one instance (antigen 5) agglutination occurred in a dilution of 1:640, but not in 1:1280. In the latter dilution the cells remained in suspension, but settled out in the antigen control. With antigen 6, it also appears as if the serum had a stabilizing effect in maintaining the cells in suspension. On the other hand, in some cases the serum definitely appears to have an opposite effect. Furthermore, antigens may vary to such an extent in their mosaic that they may react differently when placed under certain uniform conditions.

TABLE 2.—REACTIONS OF VARIANTS WITH POSITIVE AND NEGATIVE PULLORUM SERA.

Strain No.	Sera	Agglutination Titre								Antigen Control	Remarks
		10	20	40	80	160	320	640	1280		
1	P	4?	4?	4?	4?	4?	4?	PS	PS		Muddy type of agglutination
	N	PS	PS	PS	PS	PS				PS	
2	P	4	4	4	4	4	4	3	1		
	N	SS	SS	SS	SS	SS				SS	
3	P	4	4	4	4	4	4?	4?	3?		
	N	CS	CS	CS	PS	PS				PS	
4	P	4	4	4	4	4	4	3	2		
	N	SS	SS	SS	SS	SS				SS	
5	P	4	4	4	4	4	4	3	0		
	N	SS	SS	SS	SS	SS				SS	
6	P	4?	4?	4?	4?	2?	0	0	0		Fluffy precipitate in first 5 tubes
	N	0	0	0	0	0				CS	
7	P	4?	4?	4?	4?	0	0	0	0		Muddy type of agglutination
	N	0	0	0	0	0				0	
8	P	3	3	3	3	2	1	0	0		Antigen appeared clumpy
	N	0	0	0	0	0				0	
9	P	4?	4?	4?	3?	1?	0	0	0		Cells suspended in .22% saline solution
	N	SS	SS	SS	SS	SS				0	
10	P	4?	3?	2?	0	0	0	0	0		
	N	SS	SS	SS	0	0				0	
11	P	4?	4?	4?	4?	3?	2?	2?	2?		Cells suspended in .22% saline solution
	N	SS	SS	SS	0	0				0	
13	P	3?	3?	3?	2?	2?	SS	SS	SS		Cells suspended in .22% saline solution
	N	0	0	0	0	0				0	

Legend: P — positive serum
N — negative serum
4 — complete agglutination
3 – incomplete agglutination
2 — partial agglutination
1 — slight agglutination
0 — no agglutination
? — questionable agglutination
CS — complete settling of cells
PS — partial settling of cells
SS — slight settling of cells

Because of the influence of salt concentration upon the ability of a strain to remain in suspension, the twelve strains were suspended in different salt concentrations (0.11, 0.45 and 0.90 per cent) and tested against positive and negative pullorum sera. The method of preparing the antigens and the technique for conducting the agglutination test were the same as employed previously.

The data presented in Table 3 confirm the observations recorded in Table 2 in many respects, and show beyond a doubt that a decrease in electrolyte will increase the stability of the organism when in suspension. In no case was settling of cells observed in 0.11 per cent saline solution in the absence of serum. One antigen, No. 6, settled out in this salt concentration after negative serum was added, but then only in the lower serum dilutions. Antigens 6, 7, and 8 exhibited no clumping in the lower saline concentrations in the presence of positive serum, while in the higher saline concentrations fine clumps were visible. However, this clumping of cells was observed only in the first two serum dilutions. In the higher dilutions the cells had settled out and appeared similar to the antigen control. With antigen 7 definite clumping was observed in the first two dilutions, no clumping or settling in the four succeeding dilutions, but slight settling in the last and partial settling in the antigen control. It is evident that antigens 6, 7, and 8 were highly sensitive to salt and practically inagglutinable in the saline concentrations employed. Antigens 2, 4, 5, and 13 exhibited typical agglutination in the 0.9 per cent saline solution and remained in suspension in the presence of negative serum and in the antigen control. However, in the weaker salt concentrations the clumping of cells was not as marked and well defined as in a stronger concentration. Also the titre was reduced with the weaker saline concentration. It was also observed that the clumps in the lower dilutions were as a rule larger than in the higher dilutions. Furthermore, in some instances the suspension appeared more turbid after agitation in the lower dilutions than in the higher dilutions and in the antigen control. This indicated that other substances aside from the bacteria or bacterial fragments had precipitated. This phenomenon was observed even after the H-ion concentration was lowered to pH 8.4—8.6.

TABLE 3.—REACTIONS OF VARIANTS WITH POSITIVE AND NEGATIVE PULLORUM SERA IN DIFFERENT CONCENTRATIONS OF NaCl.

Strain No.	Sera	Per cent Salt	Agglutination Titre							Antigen Control	Remarks*
			20	40	80	160	320	640	1280		
1	P	.11	4	4	4	4	2	0	0		Muddy type
	P	.45	4	4	4	4	4	0	0		Muddy type
	P	.9	4	4	4	4	4	4	PS		Fine agglutination, difficult to distinguish from settling
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	SS	SS	SS	0	0			PS	
2	P	.11	4	4	4	3	1	0	0		Very fine agglutination
	P	.45	4	4	4	3	1	0	0		Fine type of agglutination
	P	.9	4	4	4	4	2	1	0		
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	0	0	0	0	0			0	
3	P	.11	4	4	4	4	2	0	0		Muddy type of agglutination
	P	.45	4	4	4	4	4	0	0		Muddy type of agglutination
	P	.9	4	4	4	4	4	PS	SS		Definite clumps in first 5 tubes
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	CS	CS	CS	CS	CS			CS	
4	P	.11	4	4	4	4	2	0	0		Very fine agglutination
	P	.45	4	4	4	4	4	1	0		Very fine agglutination
	P	.9	4	4	4	4	4	2	0		Fine agglutination
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	0	0	0	0	0			0	
5	P	.11	4	4	4	4	3	0	0		Very fine agglutination
	P	.45	4	4	4	4	3	0	0		Fine agglutination
	P	.9	4	4	4	4	4	1	0		Fine agglutination
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	0	0	0	0	0			0	

TABLE 3.—REACTIONS OF VARIANTS WITH POSITIVE AND NEGATIVE PULLORUM SERA IN DIFFERENT CONCENTRATIONS OF NaCl.—*Continued.*

Strain No.	Sera	Per cent Salt	Agglutination Titre 20	40	80	160	320	640	1280	Antigen Control	Remarks*
6	P	.11	3	2	1	1	0	0	0		Muddy type of agglutination
	P	.45	3	2	0	0	0	0	0		Muddy type of agglutination
	P	.9	2	1	PS	PS	PS	PS	PS		Fine clumping in first tube
	N	.11	PS	PS	PS	0	0			0	
	N	.45	PS	PS	0	0	0			CS	
	N	.9	PS	PS	PS	PS	PS			PS	
7	P	.11	PS	PS	PS	PS	PS	0	0		No agglutination
	P	.45	CS	PS	PS	0	0	0	0		No agglutination
	P	.9	3	1	0	0	0	0	SS		Definite clumping in first 2 tubes
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	PS	PS	PS	PS	PS			PS	
8	P	.11	SS	0	0	0	0	0	0		
	P	.45	PS	SS	SS	0	0	0	0		
	P	.9	4	2	PS	PS	PS	PS	PS		Very fine clumps in tubes 1 and 2
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	PS	PS	PS	PS	PS			PS	
9	P	.11	4	4	4	4	1	0	0		Muddy type of agglutination
	P	.45	4	4	4	4	4	4	0		Very fine agglutination
	P	.9	4	4	4	4	4	4	PS		Fine agglutination in first 5 tubes, muddy in the sixth
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	SS	SS	SS	SS	SS			PS	
10	P	.11	4	4	4	4	0	0	0		Muddy type of agglutination
	P	.45	4	4	4	PS	PS	SS	0		Very fine agglutination in first 3 tubes
	P	.9	4	4	4	4	4	CS	0		Clumps decrease in size with dilution
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	PS	PS	PS	PS	PS			CS	
11	P	.11	4	4	4	2	1	0	0		Muddy type of agglutination plus settling
	P	.45	4	4	4	4	4	4	0		Very fine agglutination, difficult to distinguish from true settling
	P	.9	4	4	4	4	4	CS	PS		Difficult to determine amount of settling and agglutination
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	PS	PS	PS	PS	PS			PS	
13	P	.11	4	4	4	3	2	0	0		Loose type of clumping
	P	.45	4	4	4	4	2	0	0		Fine clumps
	P	.9	4	4	4	4	2	0	0		
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	0	0	0	0	0			0	
Typical Pullorum Antigen	P	.11	4	4	4	4	1	0	0		Very fine agglutination
	P	.45	4	4	4	3	1	0	0		Fine agglutination
	P	.9	4	4	4	4	3	0	0		
	N	.11	0	0	0	0	0			0	
	N	.45	0	0	0	0	0			0	
	N	.9	0	0	0	0	0			0	

*Refer to legend of Table 2 for explanation of symbols.

The agglutinating response of the four antigens approached the normal more closely in Table 3 than in Table 2. It is likely that the organisms may have been altered slightly in composition during the interval between the two tests. Organisms which exhibit variation, especially in their antigenic structure, apparently may vary in the degree and type of reactions from time to time.

The agglutination titres were determined in the host in five cases from which the organisms were isolated. In every instance the organism was capable of stimulating the production of agglutinins, as will be seen in the following data:—

Strain Number	*Titre of the Host*
2	1—160
4	1—640
6	1— 80
7	1— 80
11	1—160

No significance can be attached directly to the variation in titres, since other factors aside from the organism play a role in producing agglutinins.

In a brief summary of the data presented in this section it may be stated that variants among *S. pullorum* may be isolated from naturally infected cases. The incidence of variants as observed in this investigation amounted to 13 out of 163 cases, or 7.97 per cent. While this may be considered a significant percentage, yet from the diagnostic point of view, this figure would have been reduced to zero, since these strains were identified by tests for properties other than agglutinability and colony morphology. Of course, one is unable to state to what extent such organisms may vary further under natural conditions. The variants detected in this investigation were isolated from naturally infected eggs, chicks, and adults. The behavior of the variants in NaCl solution of various concentrations and in the presence of positive and negative sera differed greatly.

VARIATION INDUCED BY ARTIFICIAL METHODS

According to Hadley, Arkwright, and others, many species of bacteria, if not all, are subject to variation. Variability in one or more characters of an organism may be the result of natural environment or artificial conditions set up in the laboratory. In certain species which have been carefully studied the majority of characters have been found liable to variation. Some investigators have ventured so far as to claim the establishment of new species. These claims, however, are few in number and since such observations cannot be corroborated at will, one feels reluctant to entertain a view of this nature.

Different methods of studying variation have been described. In this investigation attention was directed chiefly towards deviations from the normal colony type (See Figures 1 and 2). A change in colony form was selected as a starting point to study the degree and type of variation. After having ascertained variation in one character, changes in other characters such as cellular morphology, biochemical and tinctorial reactions, pathogenicity, antigenicity, and agglutinability were studied. The author is cognizant of the fact that variation may occur in certain properties such as antigenic structure and virulence, without the strain undergoing macroscopic or even microscopic changes in colony form. To detect strains that show a variation in antigenic structure and virulence would of necessity involve a large number of experimental animals. Hence, it appeared expedient to select any change in colony type as a starting point for investigation, since the main objective was to determine to what extent *S. pullorum* would lend itself to variation in some of its properties under certain conditions.

The isolation of variants was accomplished by repeated selection of single colonies. While this method may have its shortcomings, success was attained in isolating variants that appeared markedly, if not entirely, stable.

In the historical résumé it is shown that variation may be induced through several means, such as nutriment, chemical agents, aging in broth, growth in serum, bacteriophage action, etc. In this investigation repeated transfer and aging in broth were found to bring about variation in the majority of strains examined. Other methods employed proved to be less successful.

Influence of Frequent Transfer and Aging in Beef Infusion Broth

Experiment I. In this experiment four strains were employed. The source and history of the different strains are as follows:—

Strain I—Received from Miss Murphy, Department of Bacteriology, Yale University,—a sub-strain of a culture isolated from the ovary of a hen in 1930.

Strain II—Received from Miss Murphy,—a sub-strain of a culture isolated from a chick in 1929.

Strain III—Received from the Department of Veterinary Science, Massachusetts State College,—isolated from a chick in November, 1932.

Strain IV—Received from the Department of Veterinary Science, Massachusetts State College,—isolated from the ovary of a hen in October, 1932.

Strains I and II were regarded as partial variants, as the result of treatment applied by Miss Murphy to bring about variation. In her attempts she was not successful in establishing and maintaining a rough type. On plain meat extract agar these two strains formed smooth and rough colonies, the latter varying in degree of roughness. In broth, Strain I produced a flaky type of sediment, with the supernatant fluid partially turbid; while Strain II gave a uniform turbidity, with moderate sedimentation. Strains III and IV resembled a typical *S. pullorum* strain in all respects.

The strains were cultivated in 10 cc. of beef infusion broth containing 1 per cent peptone, pH 6.8 − 7.0. Transfers were made daily for a period of two weeks. After 24 hours incubation at 37° C., the broth cultures were held at room temperature. The character of growth in all broth tubes appeared to be similar to that described above for Strains I and II. Likewise, Strains III and IV exhibited no deviation from the normal type in broth.

Meat extract agar plates were streaked with broth cultures inoculated prior to the sixth transfer. Strains I and II revealed smooth and rough colonies. Both strains produced a larger cell than did typical strains of *S. pullorum*. Cultures III and IV exhibited no change.

Each set of broth cultures, after being incubated for 24 hours at 37° C., was streaked on plain meat extract agar plates. The colony type of the different strains was little altered by frequent passage through beef infusion broth.

Sixteen days after the first set of broth tubes was inoculated all broth cultures were streaked on meat infusion agar (pH 7.0). Strain I produced a rough type of colony, with a dense center surrounded by a granular outer area which was veined. Some colonies resembled the characteristic grape-leaf type of the typhoid colony. A few smooth type colonies were also observed. Colonies approaching the rough type were more abundant in the older cultures. Strain II produced a dull, dense, granular, and entire colony which was slightly irregular in outline and raised in the center. The diameter varied from two to three millimeters. Strains III and IV exhibited colony forms which appeared to be identical with the original type.

Slight variations in colonial morphology on the different plates were observed for each strain. However, it was apparent that daily transfer for a period of two weeks, and also aging in broth for this period, did not markedly alter the colonial appearance of strains that appeared typical at the outset.

After further aging of these cultures for a period of two months, Strains I and II had partially lost their rough colonial characteristics, while Strain IV exhibited a typical smooth colony and numerous extremely small colonies which appeared very irregular in shape. Meat extract broth tubes which were inoculated with the small colonies did not reveal as heavy a turbidity of growth as is usually observed with typical *S. pullorum*. Stained smears prepared from the small colonies contained cells that were highly pleomorphic. A peculiar characteristic of this variant (designated IV-a), was the production of very small "pin-point" colonies. The size of these colonies increased but little with prolonged incubation. Some of the widely separated colonies attained a size of one millimeter, and after selection and further cultivation of these larger colonies it was observed that they retained the peculiar characteristic small size. The pleomorphic cellular material consisted mostly of thick, short rods which appeared almost coccoid in shape. Filaments, large rods, club-forms and other "aberrant" types were observed.

As a matter of interest, the small type colony was transferred to hormone agar. The response of the organism led to the formation of a very irregular colony which possessed numerous projections and resembled the appearance of a tick. The structure of the colony appeared partly granular and partly or entirely striated. Stained smears from the striated portions showed mostly a mass of filamentous forms, whereas smears from the granular portion revealed a mixed pleomorphic picture.

In an attempt to develop a larger type of colony by artificial selection it was found that the majority of the colonies that developed resembled the small type in both colonial and cellular form. This process of colony selection was carried on for a period of two years. At the present writing both variants (IV-a—small type and IV-b—large type) exhibit characteristics which are essentially the same, but appear different from the original isolated variants. While the characteristic small size of the colony has been retained, the peculiar irregular colony shape of the original variant has been lost to a very marked degree. The colony appears almost typical, except for its extremely small size. The cellular morphology has been altered slightly in that the filamentous forms are not as numerous as in the original variant.

Other properties of these variants will be discussed in the latter part of this section (See Table 4).

Experiment II.—In this experiment the procedure was identical with that of Experiment I, except that 15 different strains of *S. pullorum* were employed. The history of the strains is as follows:—

Strain No.	*History*
I II III	Isolated from a chick in 1933
IV	Isolated from a hen in 1932 (Same as Strain IV in Exp. I)
V VI	Isolated from a chick in 1933
VII	Old laboratory strain which fermented maltose
VIII IX	Isolated from a chick in 1933

X	Isolated from a hen in 1933
XI	
XII	
XIII	Isolated from a chick in 1933
XIV	Isolated from a young pullet in 1932
XV	Isolated from a chick in 1933

All but two of the strains exhibited characteristics typical of *S. pullorum*. Number VII was an old strain which had acquired the property of fermenting maltose since it was first isolated. In other respects it appeared to be typical. Strain XIV, which was isolated from a young pullet in 1932, revealed cultural characteristics different from *S. pullorum* in that it grew with difficulty in different media, settled out in broth culture, and produced some atypical colonies and cell forms.

The growth appearance of the different strains in broth from day to day resembled that of *S. pullorum*, with the exception of Strain XIV, which settled out in every instance. After the fifth transfer this strain was streaked on plain meat extract agar; this yielded colonies which possessed the features of the "normal" type.

Meat extract agar plates were streaked from the last set of broth cultures of the 14 inoculated sets. The character of the growth on the plates after an incubation period of 24 hours and longer at 37° C. was, in every instance, that of typical strains.

One month after the last set of broth tubes was inoculated all of the broth cultures were streaked on agar plates. All strains exhibited some degree of colony variation from the normal. However, some strains varied more than others. This was also true of a single strain which was inoculated into different broth tubes. In the majority of the broth tubes little or no variation was observed. In those instances where colony variation was most evident agar plates were again streaked. The results revealed no sign of colony variation in some of the strains, while others produced colonies that in some instances were markedly different from the typical.

Through a process of further selection of the colonies that varied from the normal, and by repeated transfer, three definite variants were obtained. Variants VIII-a and IX-a were cultivated on meat extract agar and transferred at frequent intervals, always selecting the roughest colony type. These two types appeared to have undergone a profound change in their colonial morphology; they appeared very stable. Variants VI-a and IX-a were placed on liver infusion agar and transferred at frequent intervals. Variant VI-a exhibited a colony type that was not greatly different from the typical on this medium. The degree of colonial roughness varied from time to time, but it never approached the marked roughness of Strain IX-a. The properties of the three variants will be described later in this section. The remaining strains, while they did exhibit slight variation in colony morphology, reverted to the normal type after a few transfers on agar.

Four sets of broth cultures were streaked on meat extract agar plates two and one-half months after the last set of broth tubes was inoculated. Negative results were obtained in attempts to isolate definite colony variants.

At five and one-half months the same broth cultures were again streaked on agar plates. Three variants were isolated from Strains I, II, and XV. The variant from Strain XV gradually reverted to the parent type. The other two variants (designated as I-a and II-a) were maintained on liver infusion agar through frequent transfer.

Six months after the last set of broth tubes was inoculated three additional variants, of Strains XII and XIII, were isolated from the broth culture. One variant of Strain XIII was placed on liver infusion agar, one type of variant (XII-a) of Strain XII was cultivated on meat extract agar, and the other (XII-b) was grown on liver infusion agar. The different variants will be described more fully in another part of this section. (See Table 4.)

Experiment III. According to the results obtained thus far, the author was inclined to believe that, while only six of fifteen strains had yielded variants, the remaining strains would also produce variants as a result of transfer and aging in beef broth, if conditions were suitable and if the platings were made at the proper time. With this view in mind, 13 of the strains employed in Experiment II (I, II, III, IV, V, VII, VIII, X, XI, XII, XIII, XIV, and XV) and three additional strains (XVI, XVII, and XVIII), were subjected to the same treatment that was employed in the second experiment. The history of the three new strains is as follows:—

Strain XVI—Isolated from the ovary of a hen in 1911
by Doctor Rettger
Strain XVII—Isolated from the liver of a chick in 1917
by Doctor Rettger
Strain XVIII—Isolated from the liver of a chick in 1916
by Doctor Rettger

During the process of transferring from day to day it was observed that Strain XIV did not appear as turbid as the other cultures. The same characteristic had been noted in Experiment II. Ten days after the last transfer in broth three sets of the broth cultures were examined and plated on plain agar. The three sets included the first, seventh, and fourteenth broth culture transfers.

An examination of the bouillon cultures in the three sets revealed that Strains III, IV, V, VII, X, XIII, and XV produced a ring on the side of the tube at the surface of the broth, and also formed a heavy flaky sediment in the bottom of the tube. The remaining strains did not show these characteristics.

The agar plates that were streaked with the broth culture sets revealed definite colony variants of Strains III, V, X, XV, XVI, and XVIII. Three colony types of one strain were observed. In a few instances the colonies varied slightly in their appearance, but not sufficiently to designate them as definite types. Such colonies apparently had deviated from the normal type, and when placed under suitable environment the original characteristics re-appeared. This may also be true of certain types that seem rather remote from the normal in colonial features. Colony selection may be of no avail in stabilizing such types. The different variants isolated in this experiment will be discussed in the latter part of this section. The broth cultures were placed at room temperature and retained for further examination. The pH was determined approximately two months after the cultures had been placed in storage. Several cultures in different series were examined, and in every instance a pH of 8.8 was observed, which meant that the medium had become more alkaline (7.0 to 8.8). Uninoculated control broth tubes possessed a pH of 7.0.

Influence of Frequent Transfer and Aging in Liver Infusion Broth

Experiment IV. Since beef infusion broth appeared to be a suitable medium for producing variants by rapid transfer and aging, it seemed plausible that a more complex and favorable medium might exert an even greater influence. The liver infusion broth was prepared as follows:—

Beef liver,	500 grams
Peptone (Difco)	10 "
Tap water	1000 cc.
(pH 7.0—7.2)	

The beef liver was ground fine and added to the desired quantity of water. This was placed in the refrigerator over-night and then slowly brought to a boil. The extract was decanted and filtered off, then adjusted to pH 7.2. After the peptone was added the pH was checked before and after heating at 15 pounds steam pressure. The broth was tubed in 10 cc. quantities and sterilized.

The cultures inoculated into the liver infusion broth were the same as those which were employed in beef broth in Experiment II. The strains were transferred daily for a period of two weeks, and at different intervals liver infusion agar plates were streaked to detect any colony variation. An examination of the broth tubes from day to day revealed that a slight amount of gas was being liberated. All tubes appeared uniformly turbid except those which were inoculated with Strain XIV. This strain settled out as it did in the beef infusion broth. Liver infusion agar plates were streaked with broth cultures transferred on the first, seventh, and fourteenth days.

No definite colony variation was observed on the plates inoculated with the broth cultures. Two months after the last transfer in broth, liver infusion agar plates were inoculated with ten of the fourteen broth sets. Only a few strains in the last three inoculated sets showed growth on the plates. The hydrogen-ion concentration of the medium had changed from 7.0-7.2 to 4.5-5.8. This marked acid production, in the presence of other metabolic products, may have been responsible for the sterility of most of the cultures. Among the strains that survived none exhibited definite variation in colony form. Six strains (II, III, VIII, IX, and two cultures of Strain X, designated b and c) were transferred at three- to four-day intervals on liver infusion agar. Strains III, VIII, and IX died off after four weeks of frequent transfer. It was observed that certain strains, including all roughs and certain so-called typical strains, appeared to be rather sensitive to liver infusion agar, and that they required frequent transfer in order to maintain their viability. If the cultures are placed at a lower temperature, the viability period may be increased, but even then such cultures do not remain alive as long as on plain meat extract agar. Strain X-b during the course of frequent transfer revealed a temporary change in colony appearance which resembled some of the more stable forms. This variation in colony type reverted to the normal after two transfers. The temporary alteration can not be attributed to any known cause, since this strain had been subjected to different environments. However, it appears that the conditions in the liver infusion agar were particularly suitable for stimulating a certain type of colony which had not been observed before in this strain. Failure to stabilize this type cannot be accounted for in this instance. Unfortunately, this strain also failed to survive after it had been transferred for a period of four months. Strains II and X-c will be discussed later with the variants previously reported. (See Table 4.)

Influence of Frequent Transfer and Colony Selection on the Enhancement of Variation

Selection of variant colonies on solid medium has been demonstrated to be a valuable means of isolating types that differ from the normal parent type. Baerthlein (1912, 1918), Hadley (1927) and Arkwright (1930) have reported that selection of variants by means of colony appearance may lead to the stabilization of well-defined types. Also by frequent transfer of such variants and by selection of colonies which reveal the greatest degree of variation, certain definite forms can be established.

Experiment V. Two old strains which revealed some degree of variation in colony type were selected for this experiment. These strains were the same as Strains I and II employed in Experiment I. Both strains produced smooth and rough colonies as well as intermediate colonies. An attempt was made to select and isolate both the roughest and the smoothest types of colonies. At each transfer each type was selected, and by this procedure it was possible to isolate a rough type which appeared stable and a smooth type which at times would exhibit a certain degree of roughness. At first transfers were made every 48 hours, but later the interval was extended to from four to five days.

The rough and smooth colony types isolated from Strain I were designated A and A-1, respectively. The two types, rough and smooth, isolated from Strain II were designated B and B-1, respectively. These different colony types will be described in another part of this section. The rough types resembled each other very closely on plain meat extract agar, although slight differences could be detected at times. The rough forms from both Strains I and II appeared to be stable, since little variation was observed in the numerous transfers of these types. The smooth types did not resemble a typical smooth *S. pullorum* colony in every respect, as will be brought out later. Also type B-1 very infrequently produced a markedly rough type of colony. On one occasion during the period of 14 months of frequent transfer a papillated colony was detected in this culture. The appearance of this type was rather sudden and it disappeared in the same manner. An attempt to propagate and stabilize the papillated variant met with failure. The cellular morphology was not as striking as the colony forms, and little variation could be detected in the cell types during the period under observation. (See Table 4.)

Experiment VI. The purpose of this experiment was to determine the influence on variants and on normal *S. pullorum* strains of frequent transfer on liver infusion agar. Since it is well recognized that liver infusion agar yields a heavier bacterial growth than plain meat extract medium, the possibility suggested itself that the former might be more suitable for the isolation and stabilization of variants. Liver infusion agar is employed in some laboratories for the cultivation of strains for antigen production, and by some even for the maintaining of stock cultures. Hence, it seemed all the more important to employ this medium to determine its influence on variants and normal strains. The strains used in this experiment were:

Strain I—Same as Strain I in Experiments I and V
Strain IV-a—Variant isolated from Strain IV in Experiment I
Strain XII—Same as Strain XII in Experiments II, III, and IV
Strain XIV—Same as Strain XIV in Experiments II, III, and IV

The liver infusion agar was prepared in the same manner as in previous experiments. The strains were transferred on plates at intervals of 48 hours. Later in the experiment the interval between transfers was increased to four or five days. The cultures were incubated at 37° C. When more than one type of colony appeared on the plate, only the roughest were selected for transfer. The colonial response of Strains I, IV-a, and XIV was impressive. A striking difference was observed between these three strains and the so-called normal Strain XII. The last appeared as typical *S. pullorum* on liver infusion agar. These strains were cultivated on this medium and transferred at frequent intervals for a period of a year. During this period the colony type varied but slightly for Strains I and XII. Strain IV-a reverted partly to the normal type. The original variant type of colony was observed for four months before it reverted to the normal. Occasionally, definite rough features were observed. At the time of reversion to the normal, the original parent Strain IV-a was again placed on liver infusion agar. The growth which resulted contained colonies that were identical with those observed in the first instance. However, this last variant also exhibited a marked tendency to revert to the normal type. After eight months of frequent transfer, colony types appeared that did not resemble typical *S. pullorum*. Strain XIV also yielded a type of colony that did not remain stable. While fluctuation in colony type was observed it never approached the normal type. The different variants isolated in this experiment are designated as follows:—

C —Variant derived from Strain I
D —Variant derived from Strain IV-a (first trial)
D-1—Variant derived from Strain IV-a (second trial)
E —Variant derived from Strain XIV

Strain XII remained typical in its colonial features; variation was observed at no time in this strain (See Table 4).

Miscellaneous Attempts to Induce Variation

When this investigation was undertaken, little knowledge was available as to what methods would be most effective in bringing about variation in *S. pullorum*. Among some of the successful methods applied to other microorganisms are (a) alternate transfer in liquid and solid media, (b) cultivation in medium with increased concentration of peptone, (c) growing in deep liquid medium, (d) cultivation in meat extract solution. The author was especially interested in the influences that such methods might exert on *S. pullorum*, since similar conditions are often found in the isolation and study of this organism.

Experiment VII. An effort was made to determine the effect of alternate transfer from liver infusion broth onto beef infusion agar. Four strains employed in Experiment I were selected. The liver infusion broth was prepared in the same manner as in Experiment IV. The beef infusion agar contained 1 per cent peptone and 1.5 per cent agar (pH 7.2). The organisms were incubated in the broth for 24 hours at 37° C. and then streaked on agar plates. After incubation for 24 hours at 37° C., the roughest colonies were selected for transfer to fresh liver infusion broth. Each strain was cultivated in broth and on agar plates six times. At the termination of the transfer period no definite variation was observed in the strains treated. After a period of seven weeks several broth cultures were streaked on plates. Only two strains revealed growth but no variation. This experiment was not repeated since some of the previously mentioned experiments proved more successful in bringing about variation. It is interesting to note that the organisms in this experiment, as well as in those previously reported, grew with difficulty in liver infusion broth, and in the majority of cases died within two months.

Experiment VIII. In this experiment a study was made of the influence of peptone concentration on colony form. Five per cent peptone solution, pH 7.2, was placed in flasks in 250 cc. quantities. Meat extract broth (1 per cent peptone, 0.3 per cent meat extract, pH 7.2) was also prepared in 250 cc. quantities. Strains I, II, and IV employed in Experiment I were selected. Each strain was inoculated into a flask of peptone solution and of meat extract peptone broth. The flasks were incubated at 37° C., and at frequent intervals meat extract peptone agar plates were streaked. The flasks were incubated at 37° C. for three weeks and at room temperature for 11 weeks. While incubating at the higher temperature a heavy scum formation was observed in the flask inoculated with Strain I. Upon agitation of the flask the scum would gravitate to the bottom in floccules. Ring formation was observed in the flask containing Strain II. Heavier growth occurred in the 5 per cent peptone solution than in the meat extract peptone broth. Streaked plates made from the peptone and the broth cultures did not reveal a colony picture which differed from the original. Strains I and II, which are older than Strain IV and are not entirely normal, seemed to thrive better in the peptone solution than Strain IV. The pH increased in each instance during the 14 weeks period.

TABLE 4.—REMARKS CONCERNING COLONIAL AND CELLULAR MORPHOLOGY OF ISOLATED VARIANTS.

Original Strain No.	Variant No.	Culture Medium*	Colonial and Cellular Morphology
			Experiment No. I
IV	IV-a	P. A.	Small irregular colonies at 24 hours of age; older colonies appear more round and entire; average size of former approximately .1 mm., larger colonies .5—.75 mm. in diameter. Surface smooth, slightly convex and glistening. Structure coarsely granular to filamentous. Cells—many bizarre forms including thick filamentous, coccoid and club-shaped. Some contained granules. Typical cells were present. See Figures 3, 4, 5, 6, and 7. After frequent transfer, a colony type was produced as shown in Figure 8, with a less pleomorphic cellular morphology.
IV	IV-b	P. A.	Colonial and cellular morphology at first similar to IV-a. Later a colony type developed which moved in mass, exhibited small projections, was dome-shaped and opaque. See Figure 9. Cellular forms slightly pleomorphic.
			Experiment No. II
I	I-a	L. A.	Colony has crenated edge, thin periphery, and is almost transparent; markedly convoluted. The interior is raised, level, slightly rough, dull, and opaque. Cellular forms highly pleomorphic. See Figures 10 and 11.
II	II-a	L. A.	Colonial and cellular features similar to I-a.
VI	VI-a	L. A.	Colony with undulating edge, semi-dome shape, and prominent central portion with shallow grooves winding outward. Dull in appearance. See Figure 12. Cells markedly pleomorphic, including cells of various lengths, club-shaped and dumb-bell forms, and some filamentous types.
VIII	VIII-a	P. A.	Colony irregular in outline, periphery flat and thin; central portion raised and opaque; surface rough, due to numerous shallow valleys and ridges; brittle consistency. Size may vary from 7 mm. to less. See Figure 13. Cells slightly pleomorphic, short thick rods, approaching coccoid type.
IX	IX-a	P. A.	Colony type similar to VIII-a, but cells slightly more pleomorphic.
IX	IX-b	L. A.	Colony has undulating edge, flat surface varying in roughness and dull in appearance. Some colonies are markedly convoluted with thin periphery. Isolated colonies may attain a diameter of 2 cm. See Figures 14, 15, and 16. Cells are markedly pleomorphic, long and thick filaments. Some cells are short.
XII	XII-a	P. A.	Colony is smooth, mound-shaped, undulating in outline, opaque, and moves in mass. See Figure 17. Cells resemble normal, but a few odd shapes and filamentous forms are present.
XII	XII-b	L. A.	Colony has dentated edge and very thin periphery which is markedly convoluted, striated and tenacious. Central portion is raised, dense, and faintly convoluted. See Figure 18. Cells in the outer portion entirely filamentous, while cells from central portion approach the normal with slight variation. See Figures 19 and 20.
XIII	XIII-a	L. A.	Colony has irregular edge and periphery is thin and prominently convoluted. Inner portion raised, dense, and marked with faint convolutions. Parallel striations are also very prominent at times. See Figure 21. Cells are very pleomorphic.

TABLE 4.—REMARKS CONCERNING COLONIAL AND CELLULAR MORPHOLOGY OF ISOLATED VARIANTS.—*continued.*

Original Strain No.	Variant No.	Culture Medium*	Colonial and Cellular Morphology
			Experiment No. III
III	III-a	P. A.	Colony similar to VIII-a, Expt. II. See Figure 13.
V	V-a	P. A.	Colony has granular surface, appendages projecting from edge, moves partly in mass; cells are long and filamentous.
X	X-a	P. A.	Colony type similar to XII-a of Expt. II. Cells slightly pleomorphic.
XV	XV-a	P. A.	Colony type similar to IV-b of Expt. I. Cells — a few bizarre forms observed.
XVI	XVI-a	P. A.	Colony type similar to VIII-a of Expt. II.
XVIII	XVIII-a	P. A.	Colony type similar to VIII-a of Expt. II. See Figure 13.
			Experiment No. IV
II	II-b	L. A.	Colony morphology similar to normal type. Occasionally a rough beveled edge is observed. Interior is smooth and homogeneous. Cells—bizarre forms numerous.
X	X-c	L. A.	Colony morphology similar to normal type, cells slightly pleomorphic.
			Experiment No. V
I	A	P. A.	Colony type similar to VIII-a of Expt. II. Cell morphology slightly pleomorphic.
I	A-1	P. A.	Colony surface inclined to be slightly rough and irregular at times, with faint convolutions; edge entire and structure occasionally granular; cells pleomorphic.
II	B	P. A.	Colony similar to VIII-a of Expt. II, but appears to be somewhat butyrous in consistency and more dense. Cells long, approaching short filaments.
II	B-1	P. A.	Colony has tendency to vary in its morphology. While resembling the smooth type, it occasionally will produce rough colonies. Cells same as in Variant B.
			Experiment No. VI
I	C	L. A.	Colony has irregular edge, may appear curled; peripheral portion thin and frequently markedly convoluted and filamentous. Central portion appears raised and dense, at times filamentous. Surface appears dull, consistency butyrous. Young colonies appear very irregular, filamentous, and granular. Older colonies may resemble the Medusa-head colony and attain a diameter of 1.5 cm. Cells vary in length from the normal to long filamentous types. See Figures 22, 23, 24, and 25.
IV-a	D-1	L. A.	The variant when first placed on liver infusion agar produced a very irregular colony possessing numerous projections. The structure might be entirely granular, semi-granular, or entirely filamentous. As the colony grew larger the angular portions were filled in. Many cells of these colonies were thick filaments of various lengths. Other bizarre forms of cells were also observed. Granular types were seen frequently, especially in older cultures. The colony appeared dull and could be removed in mass. See Figures 26, 27, and 28. This colony type has reverted almost completely to smooth form.
IV-a	D-2	L. A.	This variant followed practically the same course of reversion, but not as completely, as D-1 of Expt. VI.
XIV	E	L. A.	Young colonies exhibit numerous projections. The structure of the projections and interior of the colony appears striated. Older colonies appear less angular, but have an irregular outline, convoluted and striated periphery with a raised dense center. Isolated colonies may attain a diameter of 1 cm. The cellular types in the small striated colonies consisted largely of filamentous forms. Older colonies contain cells of various sizes. See Figures 29 and 30.

*P. A.—Plain meat extract agar.
L. A.—Liver infusion agar.

Experiment IX. In this experiment the influence of the quantity of medium on colony and cellular form was studied. Meat infusion broth prepared as mentioned above was used in flasks in 300 cc. quantities and in tubes in 10 cc. amounts. Strains I, II, and IV, employed in Experiment I, and Strain VII, used in Experiment II, were studied. The flasks and tubes, after being inoculated, were incubated at 37° C. Meat infusion peptone agar plates were streaked at frequent intervals. As in the previous experiments, a heavy scum formation was observed in all strains, especially I and II. The turbidity of the broth was approximately the same in every case, except in the flask and tube inoculated with Strain I. The cultures were examined for a period of one month, with the result that no definite colony variants were detected. While Strains I and II did reveal tendencies toward colony variation, no definite variants were established. The larger quantity of broth apparently had no different effect on the strains than did the smaller quantity.

Experiment X. An attempt was made to determine the influence of meat extract solution on colony and cellular form. A 3 per cent meat extract (Difco) solution (pH 7.2) was prepared. The medium was flasked in 125 cc. quantities. Strains I, II, and IV listed in Experiment I were studied. Ordinary meat extract broth, as employed in Experiment VIII, was used as a control for determining the influence on the growth characteristics of *S. pullorum.* In the meat extract flasks it was difficult to ascertain the presence of growth by macroscopic examination. At the end of the first week of incubation agar plates were streaked from both the meat extract solution flasks and meat extract broth flasks. No growth was obtained from the meat extract solution. Apparently a 3 per cent solution of meat extract exerted a toxic effect that was detrimental to the growth of *S. pullorum.* Further investigation of the influence of meat extract as such was not continued. Lower concentrations of meat extract would probably permit growth of this organism. The flasks containing the meat extract peptone broth revealed growth, but no definite colony variants were isolated.

Summary of Results

While variants of *S. pullorum* have been reported by a few investigators to occur spontaneously, the foregoing data show that variants of this organism may be induced by artificial conditions. These results should be of much interest, since most investigators and diagnosticians in animal diseases regard *S. pullorum* as exceedingly stable in its various characteristics. Like other species of microorganisms, it will respond to certain environmental influences. Under some conditions extreme variation may be observed in which the variant does not resemble the parent strain in any of its colonial and cellular features. It will change also in other characters, as will be brought out later. Different degrees of variation may be observed in cultures that are subjected to certain influences. These changes may be temporary or the new types may be stabilized by various methods, such as frequent transfer, colony selection, and growing on special media. In this section 28 variants are reported. Several different types are included in this number, as may be seen in Table 4.

The extremely rough colony type which was stabilized on plain meat extract agar has undergone a marked change in colony appearance. As will be pointed out later, profound alterations were also observed in virulence, antigenicity, and ability to remain in suspension in saline solution. The cellular morphology of this type, while exhibiting slight pleomorphism at times, appeared on the whole to be quite stable and typical.

Another type observed on plain agar is that exhibited by variant XII-a. This type apparently has not digressed from the normal to the extent that some others have, and also shows a greater tendency to revert to the typical form. A characteristic peculiar to this type is that the colony moves in mass when disturbed with a needle. This characteristic may be due to the fact that the colony is small and mound-shaped and that its internal structure contains filamentous forms. These forms may serve as a reinforcement in retaining the colony in its entirety. An apparently similar action by these filamentous forms may be seen in XII-b, in which the periphery is largely composed of filaments which exhibit a tenacious property. Also in small colonies composed largely of filaments the entire mass moves in toto.

The different types of variants established on liver infusion agar show colonial and cellular characteristics different from those observed on plain meat extract agar. The liver agar apparently contains certain constituents that have an influence on the colony appearance and cell types. It has been observed that friable, fatty, yellowish-brown liver tissue will produce an agar that is lighter in color than that obtained from a firm, dark brown liver. The growth on agar medium prepared with the latter is not as abundant and butyrous in character as on the other medium. The liver tissue may vary in composition and thus affect the character of the growth.

In two instances during this investigation a mucoid type of colony was observed on liver infusion agar. Attempts to stabilize this type failed.

Certain variants may develop to a very impressive size on liver infusion agar. This has not been observed on plain agar, although the colony size may be markedly larger than that of the normal type. It was also observed in most instances that liver infusion agar greatly exaggerated any unusual features that were slightly noticeable in colonies growing on plain agar. Hence, liver infusion agar may serve in some instances to determine the normalcy of a strain, or at least bring out certain characteristics that may not be demonstrable with the ordinary media. The continuous cultivation of *S. pullorum* in liver infusion media may in some cases lead to temporary variation and possibly permanent change in one or more characteristics. A temporary variation was observed in one strain after having been cultivated on liver infusion agar for a period of some months. The mucoid type of colony also occurred spontaneously on liver infusion agar. Cellular types produced on this medium do not resemble the normal types, especially in the first transfer. With the organism capable of producing such responses on liver infusion agar, it appears that an antigen prepared from liver cultures may be expected not to react in the same manner as that prepared from a meat extract agar growth.

BEHAVIOR OF VARIANTS IN DIFFERENT ENVIRONMENTS

Numerous investigations, reviewed by Hadley (1927), show that organisms may lose or gain more than one property when undergoing variation. This process does not necessarily involve certain characteristics, but it appears that some properties are more frequently altered than others. Colonial and cellular morphology, and pathogenic and serologic properties seem to be most susceptible to change. Fermentative and other biochemical characteristics do not change so readily.

The variants in this investigation were studied as to their behavior in (1) broth, (2) NaCl solution, (3) fermentable substances, (4) fresh whole egg and egg yolk, and (5) the natural host.

Behavior in Broth

Arkwright (1921) and others have demonstrated that the rough colony variants may form a pellicle and yield a sediment in the bottom of the tube, with the supernatant fluid almost or entirely clear. Also, the growth of the rough type is usually retarded.

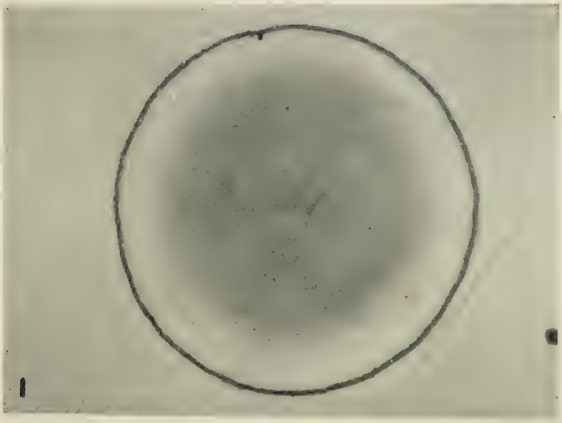
Table 5 shows the growth characteristics of the different variants in meat extract broth (1 per cent Bacto peptone and .3 per cent Liebig's meat extract, pH 7.0) at different incubation periods. The data show that 13 strains produced normal growth in broth, while 14 variants exhibited modified growth characteristics in this medium. It is interesting to note that strains D-1, D-2, IV-a, IV-b, V-a, X-a, XII-a, and XV-a are characterized by a similar type of growth in broth as well as on solid medium. Strains I-a and II-a produced growth that was slightly different in its nature from that of the aforementioned strains. The sediment was more abundant and not so compact. It is of interest to note that the variants which produced the so-called "roughest" colony produced growth in nutrient broth that appeared quite typical or normal. These results show that not all colony variant strains tend to settle out in meat extract broth. The characteristic of settling in broth apparently cannot always be associated with any definite type of colony or cellular form. Obviously, this property may vary from time to time in a given type, since earlier in this investigation variants A and B revealed a tendency to grow with difficulty and to settle out in broth. The colonial and cellular features were not observed to have changed in these two instances.

TABLE 5.—BEHAVIOR OF VARIANTS IN BROTH.

Variant No.*	Observations at End of Various Incubation Periods			
	24 hours	48 hours	72 hours	96 hours
A	1+(g)	1+(g)	N	N
A-1	N	N	N	N
B	N	N	2+	1+
B-1	N	N	N	N
C	N	N	N	N
D-1	1+	2+(g) (r)	2+(g) (r)	2+(g) (r)
D-2	—	—	2+(g) (r)	2+(g) (r)
E	N	N	N	N
I-a	3+(g)	2+(g)	2+(g) (r)	2+(g) (r)
II-a	4+(g)	3+(g)	2+(g) (r)	2+(g) (r)
II-b	N	N	N	N
III-a	2+(g)	2+(g)	2+(g)	1+(g)
IV-a	N	1+(g) (r)	1+(g) (r)	1+(g) (r)
IV-b	3+	3+(g) (r)	3+(g) (r)	3+(g) (r)
V-a	N	1+(g) (r)	1+(g) (r)	1+(g) (r)
VI-a	N	N	N	N
VIII-a	N	N	N	N
IX-a	N	N	N	N
IX-b	N	N	N	N
X-a	4+ (f)	4+(f) (r)	4+(f) (r)	4+(f) (r)
X-c	N	N	N	N
XII-a	3+(f)	3+(f)	3+(f)	3+(f)
XII-b	N	N	N	N
XIII-a	2+(g)	1+	1+	1+
XV-a	N	1+(g) (r)	1+(g) (r)	1+(g) (r)
XVI-a	N	N	N	N
XVIII-a	N	N	N	N

*Refer to Table 4 for history of variants.

Legend:
N—uniform heavy turbidity
1+—slight clearing
2+—partial clearing
3+—marked clearing
4+—complete clearing
(g)—granular precipitate
(f)—flaky precipitate
(r)—ring formation



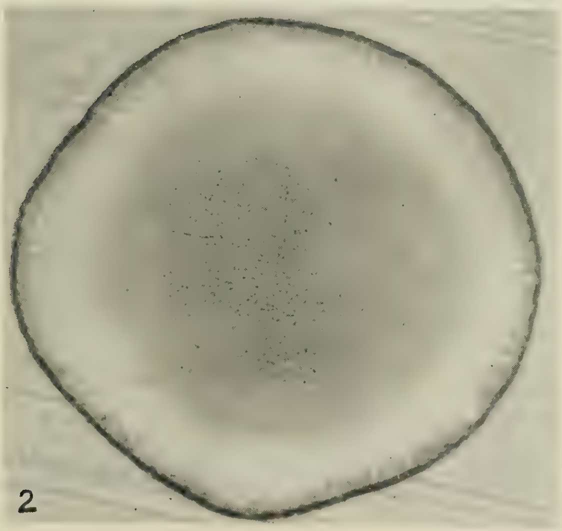
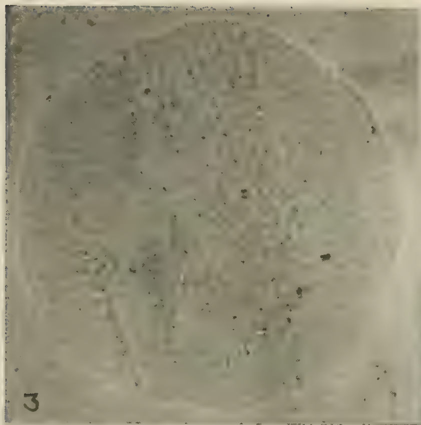
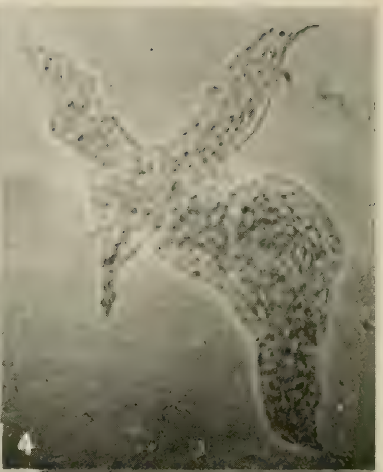
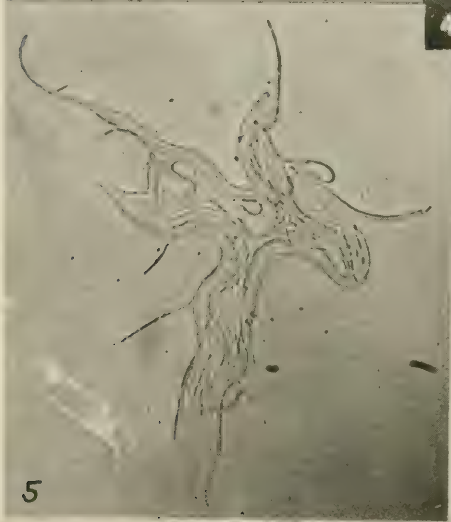


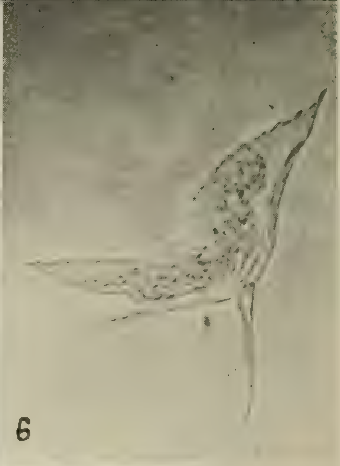
Figure 1. Typical S. pullorum colony on meat extract agar. 24 hours incubation. ×125 diameters.

Figure 2. Typical S. pullorum colony on liver infusion agar. 24 hours old. ×100 diameters.









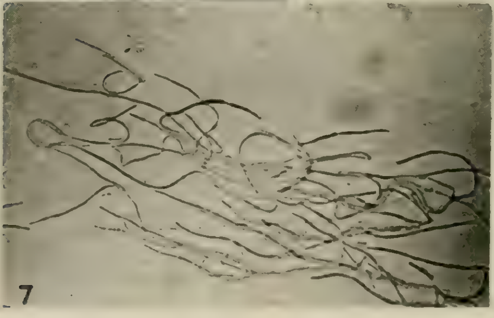


Figure 3. Strain IV. Typical colony on hormone agar. 20 hours old. ×340 diameters. (See page 20 and Table 4.)

Figure 4. Variant IV-a. A granular, irregular-shaped colony on meat extract agar. 20 hours old. ×340 diameters. (See Table 4.)

Figure 5. Variant IV-a. An irregular-shaped striated colony on meat extract agar. 20 hours old. ×340 diameters.

Figure 6. Variant IV-a. An irregular-shaped colony, partly granular and partly striated. Meat extract agar. 20 hours old. ×340 diameters.

Figure 7. Variant IV-a. Scattered and grouped threads of growth on meat extract agar. 20 hours old. ×340 diameters.

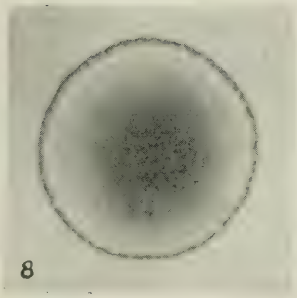
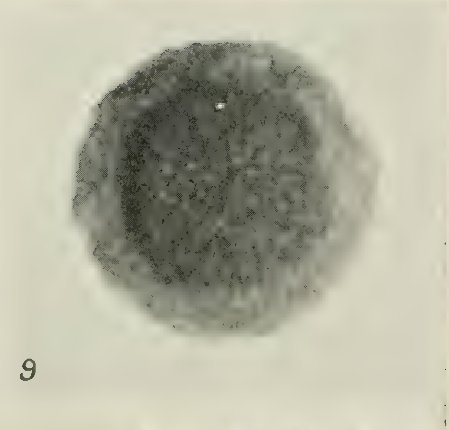
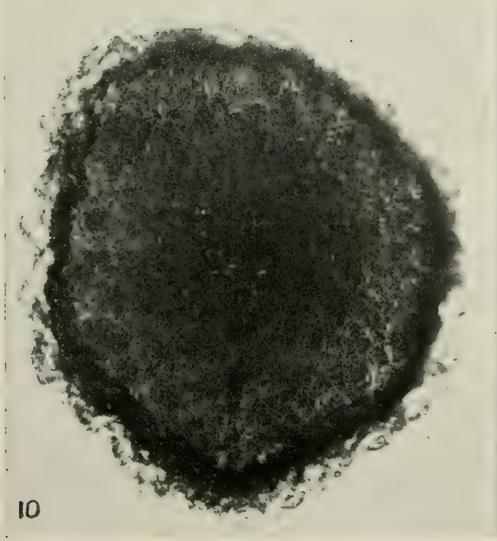
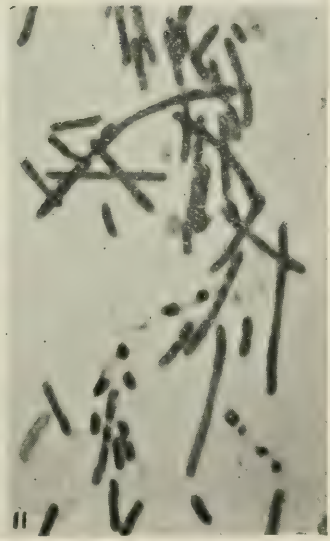
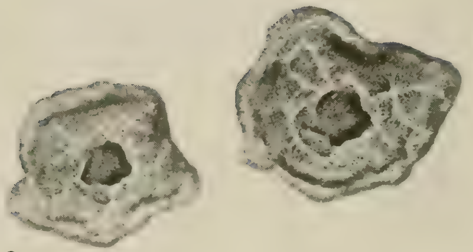


Figure 8. Variant IV-a. Two-day-old colony on meat extract agar. ×50 diameters. (See Table 4.)

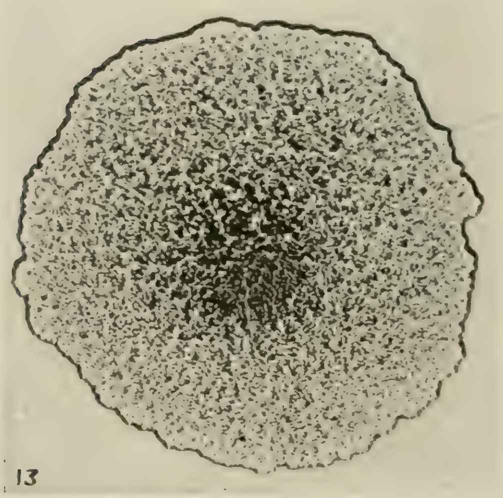
Figure 9. Variant IV-b. Two-day-old colony on meat extract agar. ×125 diameters. Colony exhibited marked opaqueness and projections. (See Table 4.)

Figure 10. Variant I-a. Two-day-old colony on liver infusion agar. ×25 diameters. (See Table 4.)

Figure 11. Variant I-a. Cells in a smear prepared from the colony illustrated in Figure 10. ×1500 diameters.



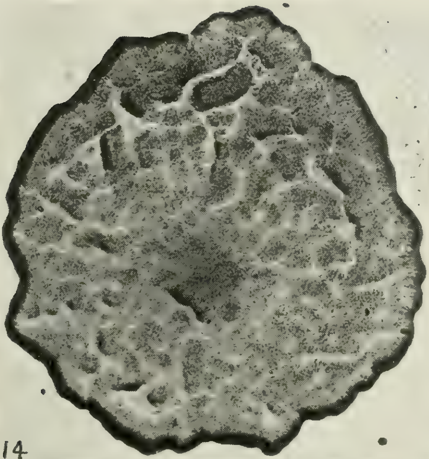
12



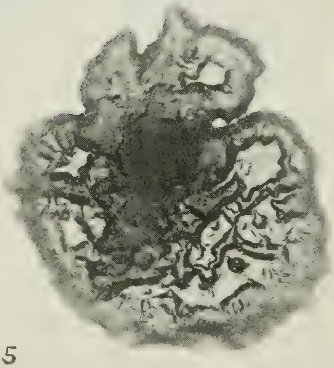
13

Figure 12. Variant VI-a. Two-day-old colony on liver infusion agar. ×11 diameters.

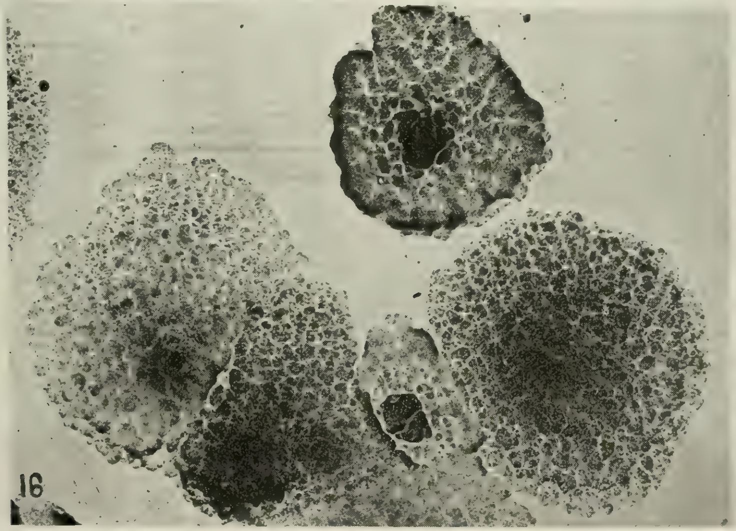
Figure 13. Variant XVIII-a. Two-day-old colony on meat extract agar. ×25 diameters. (See Table 4.)



14



15

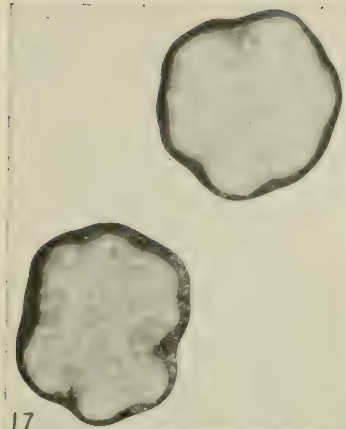


16

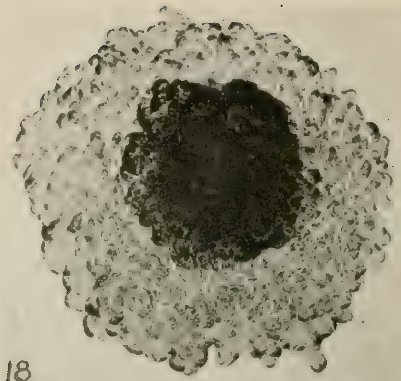
Figure 14. Variant IX-b. Five-day-old colony on liver infusion agar. Culture subjected to frequent transfer. ×11 diameters. (See Table 4.)

Figure 15. Variant IX-b. Colony type produced after passage through natural host. Liver infusion agar. Six days old. ×11 diameters. (See Table 4 and page 38.)

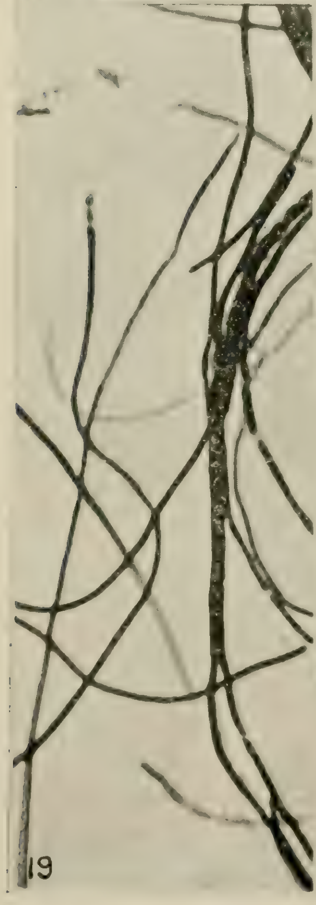
Figure 16. Variant IX-b. Slight variation in colony types. Liver infusion agar. 48 hours old. Culture maintained in whole fresh eggs. ×11 diameters. (See Table 4 and page 34.)



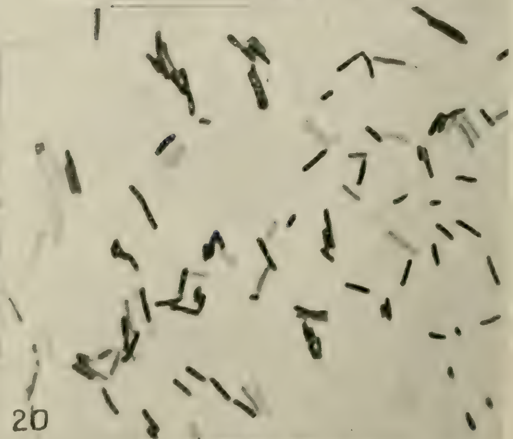
17



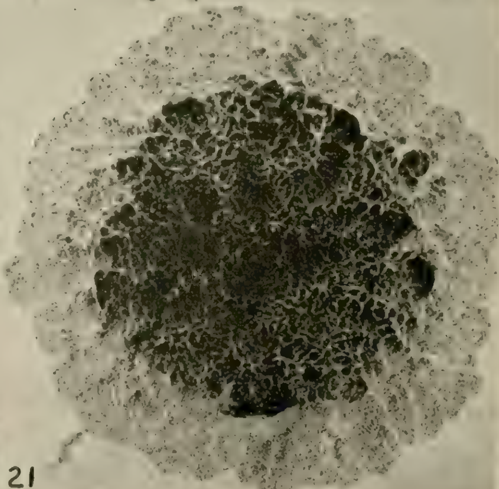
18



19



20



21

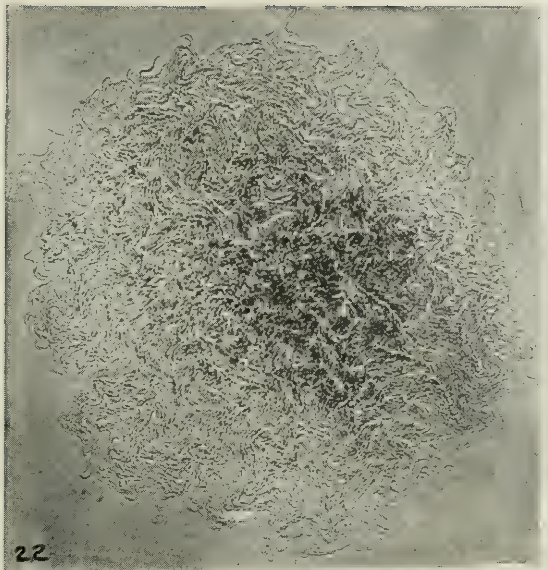
Figure 17. Variant XII-a. Two-day-old colonies on meat extract agar. ×50 diameters. (See Table 4.)

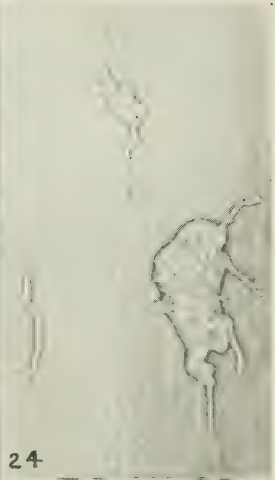
Figure 18. Variant XII-b. Three-day-old colony on liver infusion agar. ×10 diameters. (See Table 4.)

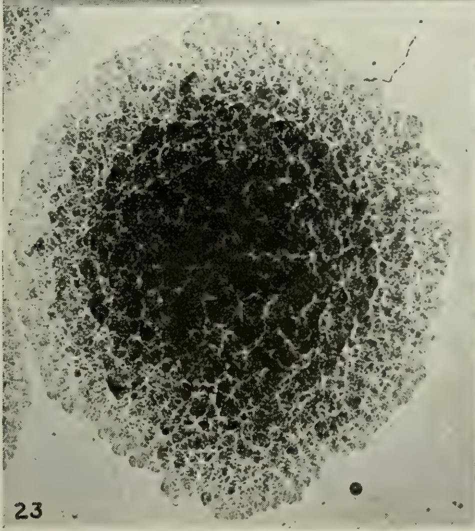
Figure 19. Variant XII-b. Filamentous forms in a smear prepared from the peripheral portion of the colony illustrated in Figure 18. ×1200 diameters.

Figure 20. Variant XII-b. Types of cells in a smear prepared from the central portion of the colony illustrated in Figure 18. ×1200 diameters.

Figure 21. Variant XIII-a. Two-day-old colony on liver infusion agar. ×20 diameters. (See Table 4.)







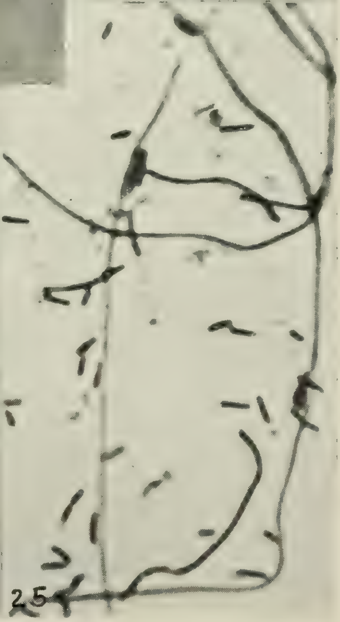
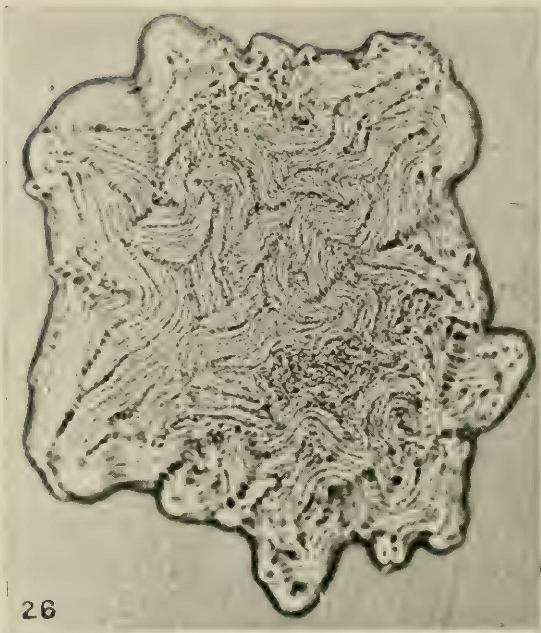


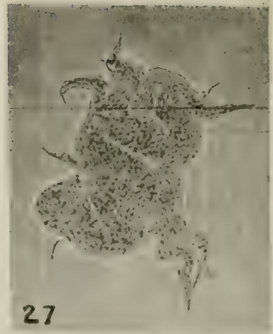
Figure 22. Variant C. Three-day-old colony on liver infusion agar. ×125 diameters. (See Table 4.)

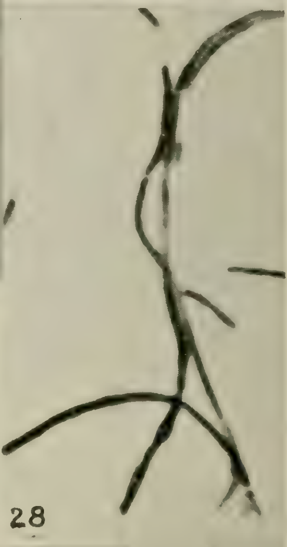
Figure 23. Variant C. Two-day-old colony on liver infusion agar. ×11 diameters. Culture maintained in whole fresh eggs. (See Table 4 and page 34.)

Figure 24. Variant C. One-day-old colonies on liver infusion agar. ×125 diameters. (See Table 4.)

Figure 25. Variant C. Cells and filamentous forms in a smear prepared from colonies illustrated in Figure 24. ×1500 diameters.







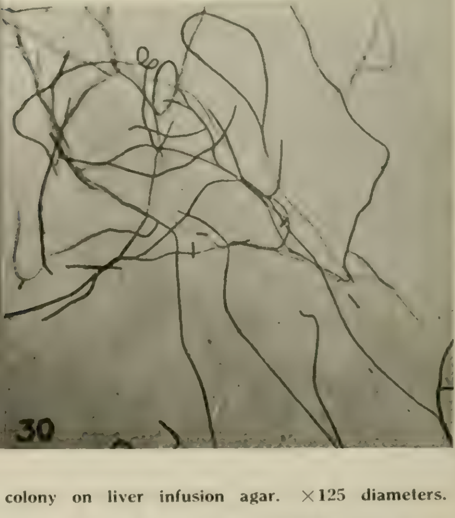


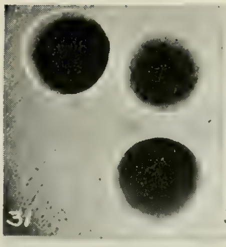
Figure 26. Variant D-1. Six-day-old colony on liver infusion agar. ×125 diameters. (See Table 4.)

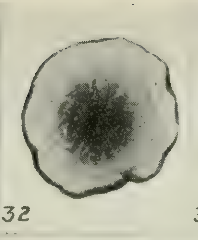
Figure 27. Variant D-1. One-day-old colony on liver infusion agar. ×125 diameters.

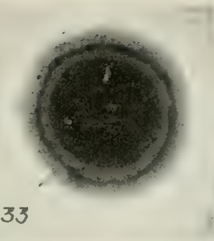
Figure 28. Variant D-1. Cells in a smear prepared from colony type illustrated in Figure 27 ×1500 diameters.

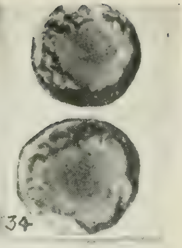
Figure 29. Variant E. One-day-old colony on liver infusion agar. ×125 diameters. (See Table 4.)

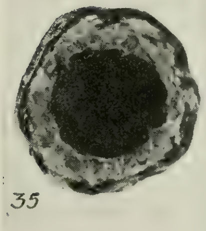
Figure 30. Variant E. Scattered filamentous forms in a smear prepared from colony type illustrated in Figure 29. ×375 diameters.

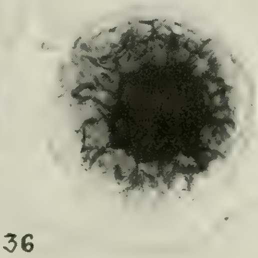


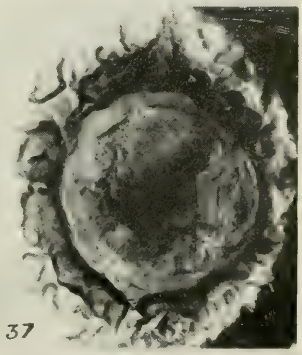


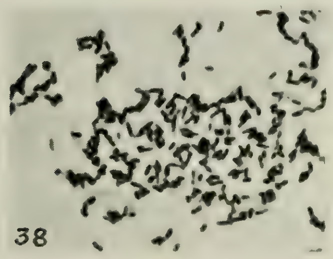


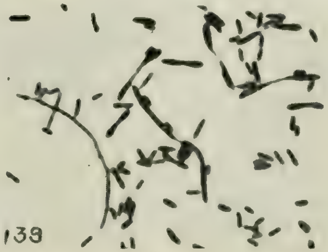


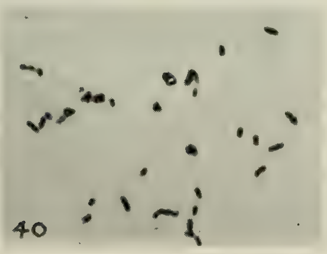












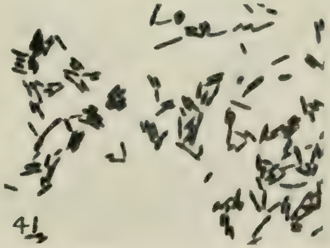


Figure 31. Variant B. Colonies of primary culture. Meat extract agar. 40 hours old. ×15 diameters. (See page 36.)

Figure 32. Variant B. Isolated colony in primary culture from spleen. Reveals an undulating edge due to the debris on the agar surface. Meat extract agar. 40 hours old. ×15 diameters.

Figure 33. Variant B. Isolated colony in primary culture from spleen. Meat extract agar. Six days old. ×15 diameters.

Figure 34. Variant B. Congested colonies in primary culture from spleen. Liver infusion agar. Two days old. ×15 diameters.

Figure 35. Variant B. Isolated colony in primary culture from spleen. Liver infusion agar. Two days old. ×15 diameters.

Figure 36. Variant B. Isolated colony in primary culture from spleen. Liver infusion agar. Six days old. ×25 diameters.

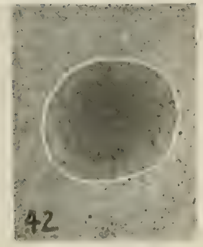
Figure 37. Variant B. Isolated colony in primary culture from liver. Liver infusion agar. Six days old. ×15 diameters.

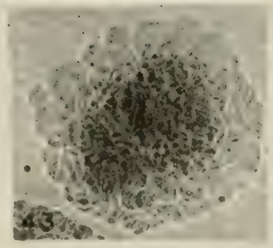
Figure 38. Variant B. Cells in a smear prepared from colony illustrated in Figure 32. ×1200 diameters.

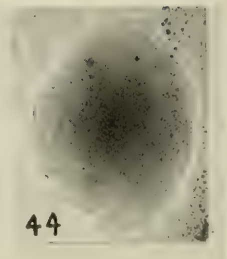
Figure 39. Variant B. Cells in a smear prepared from colony type illustrated in Figure 35. ×1200 diameters.

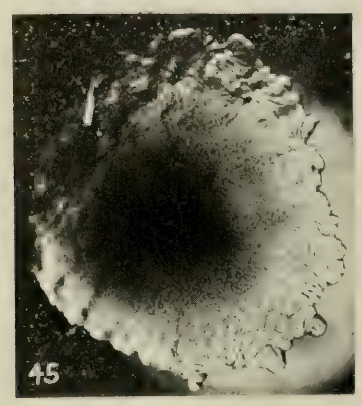
Figure 40. Variant B. Cells in a smear prepared from colony type illustrated in Figure 31. ×1200 diameters.

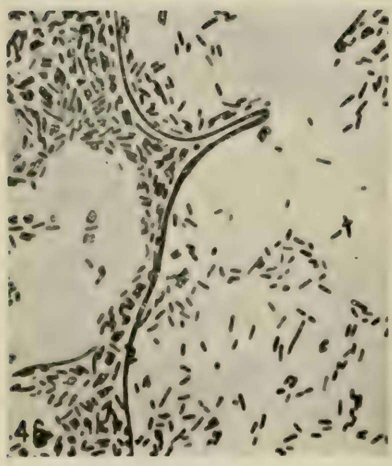
Figure 41. Variant B. Cells in a smear prepared from colony type illustrated in Figure 34. ×1200 diameters.











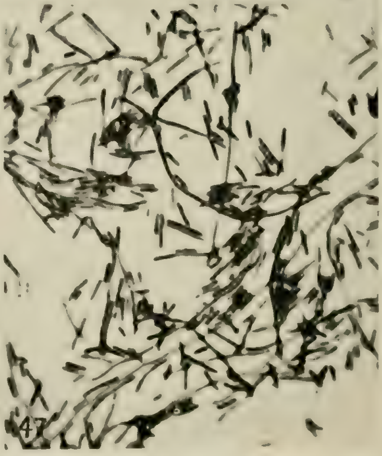


Figure 42. Variant E. Isolated colony on primary culture. Meat extract agar. 96 hours old. ×17 diameters. (See page 36.)

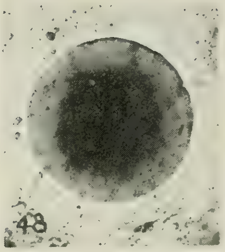
Figure 43. Variant E. Colonies on primary culture. Liver infusion agar. 72 hours old. ×17 diameters.

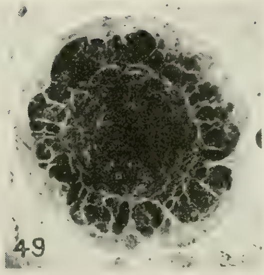
Figure 44. Variant E. Isolated colony on primary culture. Faint convolutions are visible. Meat extract agar. 48 hours old. ×15 diameters. (See page 37.)

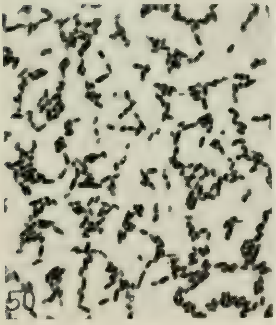
Figure 45. Variant E. Isolated colony on primary culture. Irregular edge and numerous and prominent convolutions. Liver infusion agar. 48 hours old. ×15 diameters.

Figure 46. Variant E. Cells in a smear prepared from colony illustrated in Figure 44. Long filaments occasionally present. ×1200 diameters.

Figure 47. Variant E. Cells in a smear prepared from colony illustrated in Figure 45. Numerous short and long filamentous forms. ×1200 diameters.







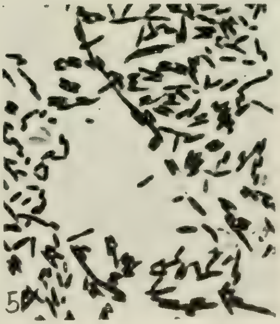
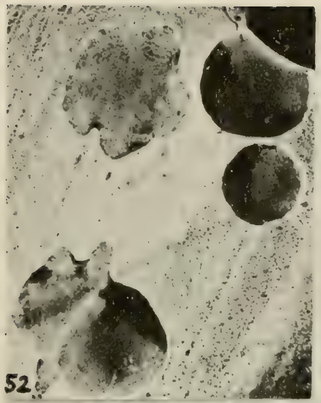


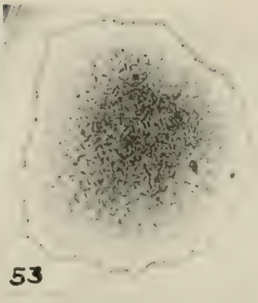
Figure 48. Strain IV. Isolated colony on primary culture. Meat extract agar. 40 hours old. ×15 diameters. (See page 37.)

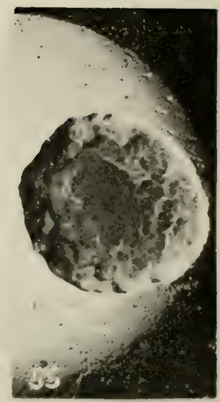
Figure 49. Strain IV. Isolated colony on primary culture. Liver infusion agar. 40 hours old. ×15 diameters.

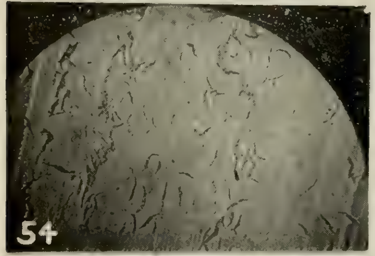
Figure 50. Strain IV. Cells in a smear prepared from colony illustrated in Figure 48. ×1200 diameters.

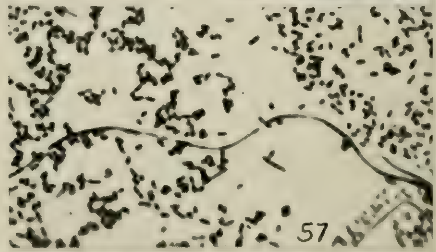
Figure 51. Strain IV. Cells in a smear prepared from colony illustrated in Figure 49. ×1200 diameters.

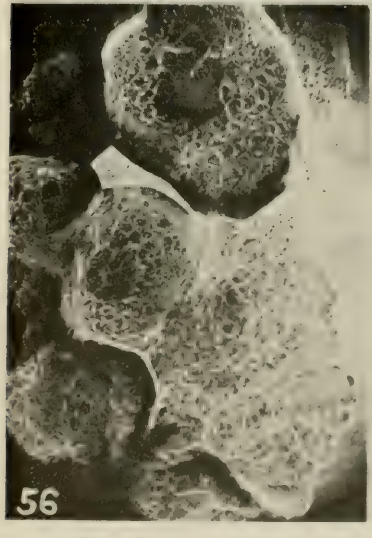


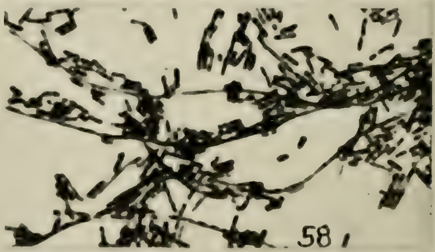












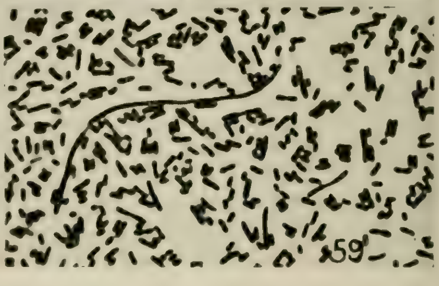


Figure 52. Strain XIV. Rough and smooth colonies on primary culture. Meat extract agar. 24 hours old. ×20 diameters. (See page 37.)

Figure 53. Strain XIV. Rough isolated colony on meat extract agar. Primary culture. 72 hours old. ×15 diameters.

Figure 54. Strain XIV. Small irregular-shaped colonies on meat extract agar. Transfer from colony illustrated in Figure 53. 18 hours old. ×35 diameters.

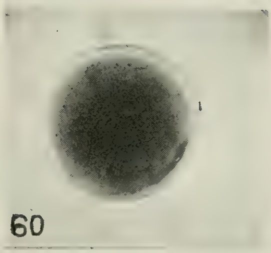
Figure 55. Strain XIV. Colonies on liver infusion agar. 24 hours old. ×15 diameters.

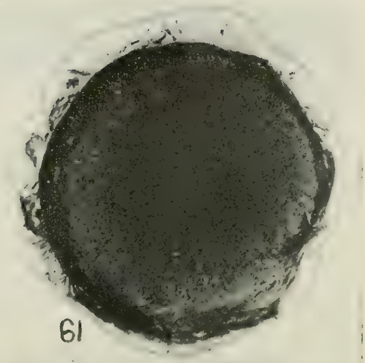
Figure 56. Strain XIV. Congested colonies on liver infusion agar. Periphery of the growth exhibits numerous convolutions. 40 hours old. ×20 diameters.

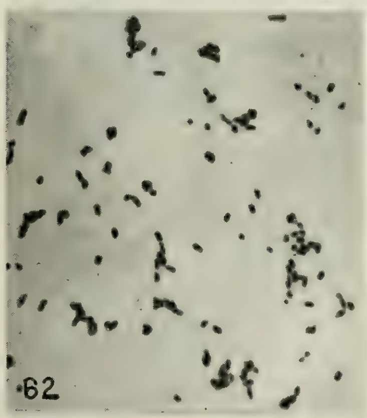
Figure 57. Strain XIV. Cells in a smear prepared from rough colonies illustrated in Figure 52. ×1200 diameters.

Figure 58. Strain XIV. Cells in a smear prepared from colonies illustrated in Figure 56. ×1200 diameters.

Figure 59. Strain XIV. Cells in a smear prepared from growth on meat extract agar. ×1200 diameters.







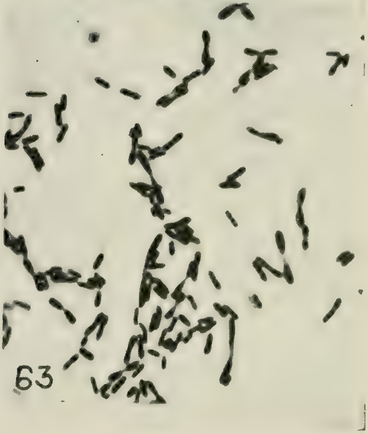
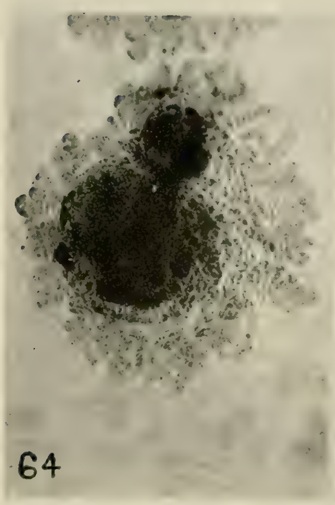


Figure 60. Strain 11706. Isolated colony on meat extract agar. Primary culture. 48 hours old. ×15 diameters.

Figure 61. Strain 11706. Isolated colony on liver infusion agar. Primary culture. 48 hours old. ×35 diameters.

Figure 62. Strain 11706. Cells in a smear prepared from growth on meat extract agar. Primary culture. ×1200 diameters.

Figure 63. Strain 11706. Cells in a smear prepared from growth on liver infusion agar. Primary culture. ×1200 diameters.



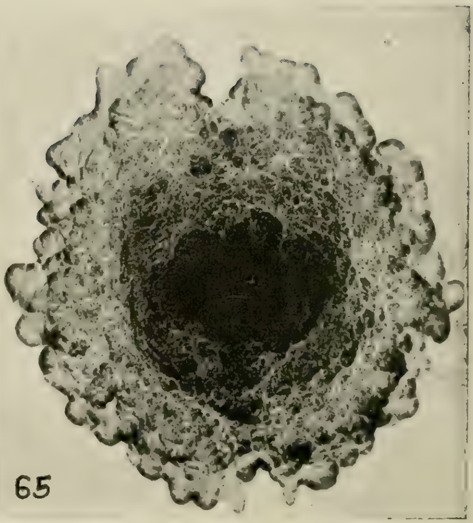
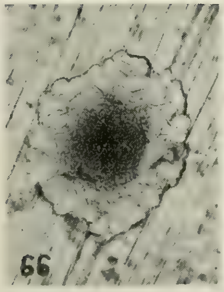
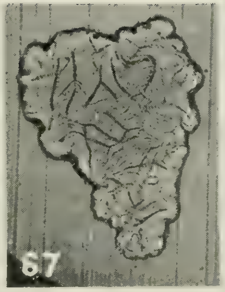
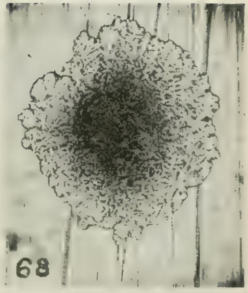


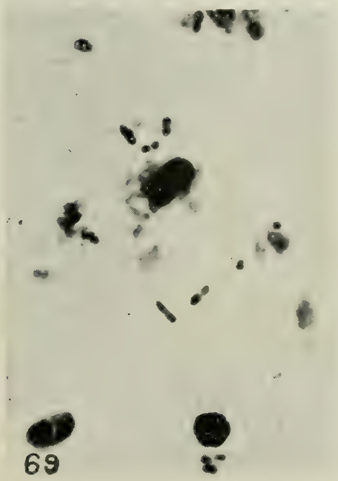
Figure 64. Variant XII-b. Colony type on primary culture isolated from yolk of chick. General features similar to those of the colony illustrated in Figure 18. Liver infusion agar. Five days old. ×11 diameters. (See page 39.)

Figure 65. Variant XII-b. Colony type on primary culture isolated from necrotic tissue at site of inoculation. General features resemble those of colony type illustrated in Figure 18. Liver infusion agar. Five days old. ×11 diameters. (See page 39.)









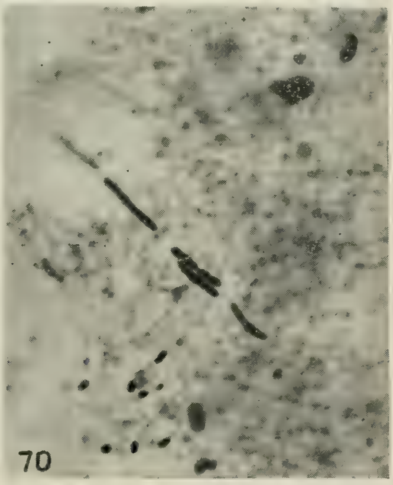


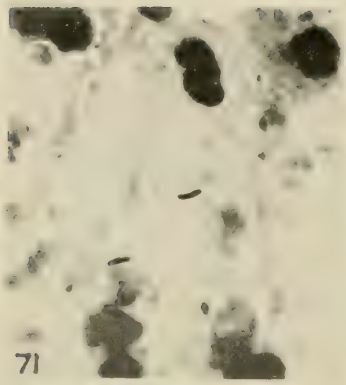
Figure 66. Variant C. A colony type with an irregular edge and markedly convoluted surface. Primary culture on liver infusion agar. Colony is isolated. 24 hours old. ×11 diameters. (See Table 4 and page 39.)

Figure 67. Variant D-1. A colony type with a very irregular outline. Surface prominently convoluted and striated. Primary isolation from necrotic tissue. Liver infusion agar. 24 hours old. ×40 diameters. (See Table 4 and page 39.)

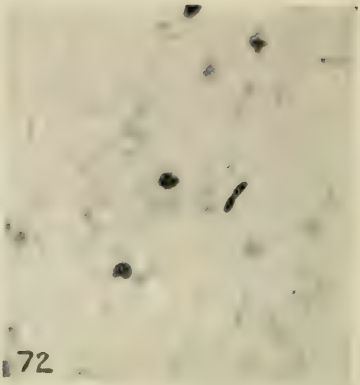
Figure 68. Variant E. Colony type isolated from necrotic tissue. Primary isolation on liver infusion agar. Colony with an irregular edge and finely convoluted surface. Four days old. ×15 diameters. (See page 39.)

Figure 69. Strain 11706. Cells in a tissue smear prepared from an abscess in an infected chick which yielded pure cultures of *S. pullorum*. ×1200 diameters. (See page 39.)

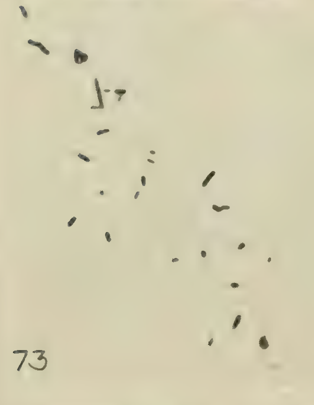
Figure 70. Strain XIV. Cellular types in a smear prepared from unabsorbed yolk of a chick. Typical cells and short filaments may be seen. ×1200 diameters. (See page 39.)



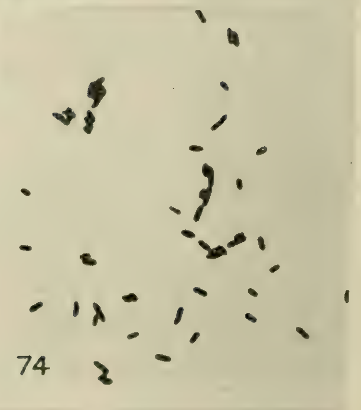
71



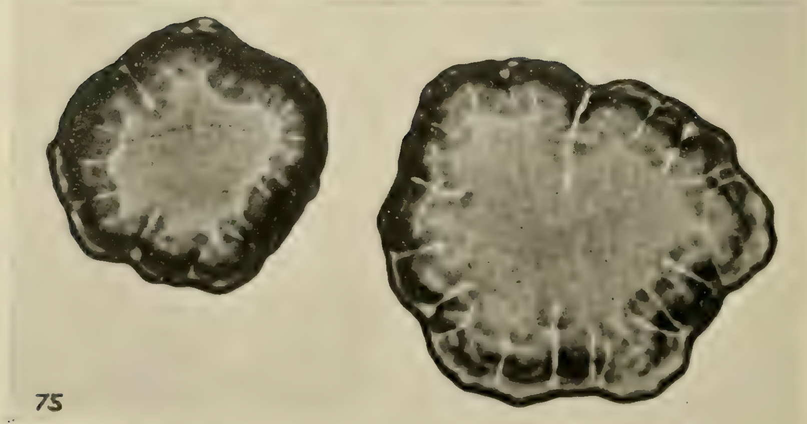
72



73



74



75

Figure 71. Variant IX-a. Cells in a tissue smear prepared from the spleen of an adult bird that died from a septicemic form of the disease. Cells, while slightly larger, resemble typical S. pullorum. ×1200 diameters. (See page 39 and Figures 73 and 74.)

Figure 72. Variant IX-a. Cells occurring in pairs. Same preparation as represented in Figure 71. ×1200 diameters.

Figure 73. Variant IX-a. Cells in a smear prepared from a meat extract agar culture isolated from the spleen tissue represented in Figures 71 and 72. ×1200 diameters.

Figure 74. Variant IX-a. Cells in a smear prepared from a liver infusion agar culture isolated from the spleen tissue represented in Figures 71 and 72. ×1200 diameters.

Figure 75. Variant XII-a. Colony type on primary isolation from yolk of chick. Meat extract agar. 96 hours old. ×50 diameters. (See Table 4 and page 44.)

Behavior in Saline Solution

The property of auto-flocculation or agglutination of cultures was first reported by Nicolle, Steinhardt, Savage, and others. This phenomenon was looked upon as being similar to the agglutination reaction which occurs between a saline emulsion of cells and agglutinating serum. Furthermore, it was claimed that the end result in the two phenomena cannot be differentiated. This statement cannot be applied to the reaction of all *S. pullorum* variants, since the type of reaction can readily be distinguished from the true typical agglutination in the majority of cases. It is also recognized by some investigators that the so-called true "R" variant is characterized by its instability in saline solution. In order to determine whether this applies also to *S. pullorum* variants, the various types that have been isolated were placed in different concentrations of NaCl solution. The suspensions were prepared from cultures incubated at 37° C. for 48 hours. Table 6 shows the reactions of different variants. The results in this table reveal that different types of variants may exhibit the same type and degree of reaction. For instance, Variants D-1, D-2, IV-a, IV-b, V-a, X-a, and XII-a do not exhibit so much settling as do some other variants which are characterized by a colony form that is more remote from the normal type. However, some very rough colony types do appear more stable in saline solution than variants that are less rough in nature. The precipitate in some cases may be organized in clumps, and in others it may be re-suspended in a homogeneous emulsion. The extremely rough colonies developing on plain agar are characterized by their brittleness, which thus far has made it impossible to produce a uniform homogeneous suspension. Grinding of such cultures in a mortar greatly reduces the size of the clumps, but does not prevent the cells from settling. The rough variants on liver infusion agar produce a suspension in saline solution which is practically free from clumps which are visible to the naked eye. The process of settling may occur within a few minutes after the cells are suspended in the salt. The degree of clearing may be as complete as in true "four plus" agglutination. Partial or complete clearing may baffle one in the routine testing of fowl for pullorum disease, especially when slight clumping is also present. Such a reaction may in certain respects resemble that of a doubtful or non-specific reacting bird. Hence it appears that strains employed for the preparation of antigen which is to be used for serological purposes may cause considerable trouble if their stability in salt solution is decreased through certain environmental influences.

Behavior in Fermentable Substances

In this experiment an effort was made to determine the ability of variants to attack different fermentable substances, and to observe the character of growth. The different variants (A, A-1, B, B-1, C, D-1, D-2, E, I-a, II-a, II-b, III-a, IV-a, IV-b, V-a,VI-a, VIII-a, IX-a, IX-b, X-a X-c, XII-a, XII-b, XIII-a, XV-a, XVI-a, XVIII-a) were tested in the following fermentable substances: Arabinose, dextrine, dextrose, dulcitol, galactose, inositol, inulin, lactose, levulose, maltose, mannitol, raffinose, rhamnose, salacin, sucrose and xylose. It may be stated that the variants attacked the same carbohydrates as did the typical *S. pullorum* strains or types. However, retarded growth and delayed fermentation were exhibited by some variants, particularly variants B and B-1. Levulose was not attacked by all of the variants, and most strains which acted upon it showed late acid production. Few produced gas with this carbohydrate. Some strains exhibited a settling of cells and clearing of the supernatant fluid, which was especially true when acid produc-

TABLE 6.—BEHAVIOR OF VARIANTS IN DIFFERENT CONCENTRATIONS OF SODIUM CHLORIDE.

Variant No.*	Concentrated Suspension of Cells .9% Salt	Dilute Suspension of Cells**			Observation Period Hours
		.9% Salt	.45% Salt	.11% Salt	
A	CS	PS	SS	SS	24
	CS	PS	SS	SS	48
A-1	0	0	0	0	24
	0	0	0	0	48
B	CS	PS	SS	SS	24
	CS	PS	SS	SS	48
B-1	CS	PS	SS	0	24
	CS	PS	SS	0	48
C	PS	PS	0	0	24
	PS	PS	SS	0	48
D-1	SS	0	0	0	24
	SS	SS	SS	SS	48
D-2	PS	PS	PS	PS	24
	PS	PS	PS	PS	48
E	CS	CS	CS	0	24
	CS	CS	CS	SS	48
I-a	CS	CS	CS	CS	24
	CS	CS	CS	CS	48
II-a	CS	CS	CS	PS	24
	CS	CS	CS	PS	48
II-b	PS	PS	PS	PS	24
	PS	PS	PS	PS	48
III-a	CS	PS	PS	SS	24
	PS	PS	PS	SS	48
IV-a	0	0	0	0	24
	SS	SS	SS	SS	48
IV-b	PS	SS	SS	SS	24
	PS	SS	SS	SS	48
V-a	SS	0	0	0	24
	SS	0	0	0	48
VI-a	CS	CS	CS	CS	24
	CS	CS	CS	CS	48
VIII-a	CS	PS	PS	SS	24
	CS	PS	PS	SS	48
IX-a	CS	PS	SS	SS	24
	CS	PS	SS	SS	48
IX-b	CS	CS	0	0	24
	CS	CS	0	0	48
X-a	PS	SS	SS	SS	24
	PS	SS	SS	SS	48
X-c	SS	SS	SS	SS	24
	SS	SS	SS	SS	48
XII-a	SS	0	0	0	24
	SS	0	0	0	48
XII-b	PS	SS	SS	SS	24
	PS	SS	SS	SS	48
XIII-a	CS	CS	PS	SS	24
	CS	CS	PS	SS	48
XV-a	0	0	0	0	24
	0	0	0	0	48
XVI-a	CS	PS	PS	SS	24
	CS	PS	PS	SS	48
XVIII-a	PS	PS	SS	SS	24
	PS	PS	SS	SS	48

*Refer to Table 4 for history of variants.

**Turbidity equal to tube 1 of McFarland nephelometer scale.

Legend: CS—complete settling
PS—partial settling
SS—slight settling
0—no settling

tion occurred. These results seem to show that, on the whole, the variants have undergone very little or no change in their fermentative powers.

Behavior in Fresh Whole Egg

In this experiment seven variants (C, D-2, E, IV-a, IV-b, VI-a, and IX-b) and their parent strains were cultivated in fresh whole eggs. The purpose of this experiment was to determine whether a natural environment, such as is found in the whole egg, would bring about a change in the colonial morphology of the variants and their parent strains. The fresh eggs were obtained from flocks that had revealed no signs of pullorum infection for at least two years. The cultures were suspended in 0.9 per cent saline solution and injected into the yolk through a small opening in the shell with a hypodermic syringe. The opening was sealed with hot paraffin after the inoculation. Measures for insuring sterility were observed in every step of this process. The eggs were incubated at 37° C. At each transfer tubes containing sterile saline solution were inoculated with yolk from inoculated eggs. The saline-yolk mixture was then injected into fresh eggs. Agar plates were also streaked with the saline yolk mixture, in order to check for purity and to study colony morphology. During the first part of this experiment transfers were made approximately once a week, while later the interval between transfers was extended to two weeks.

Table 7.—Influence of frequent transfer in fresh eggs on the colony morphology of *S. pullorum*.

Transfer No.	Days After Previous Transfer	Colony Morphology of Strains											
		Variant Strains							Normal Strains				
		C	D-2	E	IV-a	IV-b	VI-a	IX-b	I	IV	VI	IX	XIV
1	0	R	RS	R	SR	SR	RS	R	SR	S	S	S	S
2	8	R	RS	R	SR	SR	RS	R	SR	S	S	S	S
3	8	R	SR	R	S	SR	RS	R	SR	S	S	S	S
4	6	R	SR	R	S	SR	RS	R	SR	S	S	S	S
5	7	R	SR	R	S	SR	R	R	S	S	S	S	S
6	7	R	RS	R	SR	SR	RS	R	SR	S	S	S	S
7	7	R	SR	R	S	SR	RS	R	S	S	S	S	S
8	15	R	SR	R	S	SR	RS	R	SR	S	S	S	S
9	15	R	SR	R	S	SR	RS	R	SR	S	S	S	S
10	13	R	RS	R	S	SR	R	R	S	S	S	S	S
11	14	R	RS	R	S	RS	RS	R	SR	S	S	S	S
12	12	R	RS	R	S	RS	RS	R	SR	S	S	S	S
13	21	R	RS	R	S	RS	RS	R	SR	S	S	S	SR
14	15	R	RS	R	S	RS	RS	R	SR	S	S	S	S
15	17	R	SR	R	S	SR	R	R	SR	S	S	S	S

Legend: R—rough type
RS—rough type predominating
SR—smooth type predominating
S—smooth type

Table 7 gives the number of passages in whole fresh eggs, the number of days between transfers, and the colony type for each strain. The terms "S" and "R" were selected to describe the type of colony produced. However, in this instance these terms are employed in a relative sense. The appearance of a rough colony may vary considerably, yet fall into the category of roughness; likewise, a culture may resemble the "S" type more closely than the "R" form, yet not be identical with the normal smooth type. In Table 7 it may be observed that three variants with a rough colony type did not change at any time to the extent that the colony type resembled the smooth form. The four remaining variants exhibited some degree of fluctuation in their colony morphology. (See Figures 12, 16, and 23.) Two parent strains (I and XIV) also manifested a variation in colony type. However, as mentioned earlier, these two strains cannot be considered as stable, normal types. According to the results obtained, one is led to believe that the colonial morphology of variants and typical, smooth strains seems to be affected but slightly when cultivated in whole fresh eggs. This observation may have a very important bearing upon current methods of preserving antigen stock cultures. It would seem that the change in environmental conditions for this organism may not be so great in the egg as in agar slope cultures maintained at different temperatures.

At the time of three different transfers (tenth, eleventh, and fifteenth), the growth from the streaked plates was placed in different concentrations of NaCl solution in order to determine the stability of the organism in suspension. Table 8 shows that all variants exhibited some degree of salt sensitiveness. Three strains, among the typical group exhibited a slight degree of instability. However, two of these strains (I and XIV) are erratic in their behavior and almost always will pass for typical, smooth types. From the results given in Table 8, it appears that little or no change occurred in the behavior of any of the strains in NaCl solution following frequent transfer and cultivation in whole egg.

TABLE 8.—INFLUENCE OF FREQUENT TRANSFER IN FRESH EGGS ON THE CELLULAR STABILITY OF *S. pullorum* AS REVEALED IN SALINE SOLUTIONS

Transfer No.	Salt Solution	Cellular Stability of Strains											
		Variant Strains							Normal Strains				
		C	D-2	E	IV-a	IV-b	VI-a	IX-b	I	IV	VI	IX	XIV
10	.9%	PS	SS	PS	PS	SS	CS	PS	PS	SS	0	0	PS
	.45%	0	0	0	SS	SS	0	0	0	0	0	0	0
	.22%	0	0	0	SS	SS	0	0	0	0	0	0	0
11	.9%	PS	0	PS	PS	0	PS	CS	SS	SS	0	0	SS
	.45%	0	0	PS	SS	0	PS	PS	—	0	0	0	0
	.22%	0	0	SS	SS	0	SS	0	0	0	0	0	0
15	.9%	PS	0	SS	SS	0	CS	0	0	0	0	0	SS
	.22%	0	0	0	SS	0	SS	0	0	0	0	0	0
	.11%	0	0	0	SS	0	0	0	0	0	0	0	0

Legend: CS—complete settling
PS—partial settling
SS—slight settling
0—no settling
(—)—no suspension

The cultivation of variants in fresh egg yolk placed in sterile tubes did not prove as satisfactory as the whole-egg method for maintaining the different types. The egg yolk-tube method is objected to for the reason that the yolk undergoes desiccation, a change in composition, and, in all probability, an alteration in appearance. Environmental factors seem to exert a greater influence in the egg-yolk than in the whole-egg method. Considerable difficulty was encountered in keeping the variants viable during their sojourn in the yolk. In a few instances an incubation period of two weeks was sufficient to cause death. Also, this method involves a greater risk of contamination. The organism apparently attacks the components of the yolk material, since the inoculated tubes differed materially in appearance from the uninoculated. In some instances the contents, after an incubation period of two weeks, resembled the interior of diseased ova in adults and unabsorbed yolk in young stock.

The observation that variants may pass through the egg unchanged in their colony form is substantiated by the above findings.

Behavior of Variants in the Natural Animal Host

In this experiment the behavior of the variants in chicks and adult fowl was studied. Special attention was directed toward determining the stability of the types in the living host. Pathogenic and serologic characters were studied in greater detail in another series of experiments. Pullorum disease-free stock, including chicks and mature fowl, was employed in this experiment. Both variants and typical normal strains were investigated, the latter being regarded chiefly as controls. Saline suspensions were prepared from 24-hour agar cultures. The concentration was adjusted to a turbidity of tube 2 of McFarland's nephelometer scale in all instances except one, in which the turbidity was equal to tube 1.25.

Four different lots of chicks were fed or inoculated with suspensions of the organism. The chicks exposed to the different strains were confined in separate cages and cared for in such a manner as to minimize the possible hazard of cross infection. In a few instances the chicks were intentionally chilled in order to reduce their resistance to the invasive power of the organism. A period of approximately two weeks elapsed between the time of inoculation or feeding and the necropsy. Chicks that succumbed during the observation period were necropsied within a short time after death. Cultures were made from the liver, spleen, yolk, and in some instances other organs or tissues, depending upon the pathological picture encountered. Tissue impression smears were made from chicks in the first few inoculated series for the purpose of determining the presence and morphology of the organism in the host. Only those smears prepared from tissues which yielded *S. pullorum* in pure culture were stained with a dilute solution of Hucker's gentian violet, and examined. The isolated cultures were checked for type in broth containing dextrose, maltose, lactose, sucrose, and in some instances dulcitol; by the Gram staining method; also in a number of cases by the agglutination test.

No. 1. In this lot, 26 chicks were fed with three variants (C, D-1, and E) and one typical strain designated 11,706, which had been recently isolated from the ovary of a hen. The dose was 0.03 cc. The results obtained from feeding the different organisms are presented in Table 9, and show that the percentage of infected chicks was very low. Three of the four chicks which revealed *S. pullorum* had been inoculated with the typical strain, 11,706. The recovered organism resembled the original strain in colonial and cellular morphology. The strain recovered from the group infected with Variant E also appeared identical with the original, and was agglutinated by positive pullorum serum. The cells settled out in the presence of negative serum and in the antigen control. A few of the cultures were isolated in duplicate on meat extract and liver infusion agars. Infrequently growth occurred on one medium and not on the other, especially when but few colonies were isolated from an organ. Occasionally only one colony was observed on a plate, which suggests that the amount of tissue used for inoculating is an important factor in obtaining positive isolations.

No. 2. Eighty-two chicks obtained from the same source as those in No. 1 were fed and inoculated with six variants (B, C, D-1, E, VI-a, and IX-b) and four so-called smooth types (IV, XIV, 11,706, and 18,292). For a description of the variants the reader should refer to Table 4. Saline suspensions were prepared from 24-hour cultures, and the turbidity was standardized to tube 2 of McFarland's nephelometer. Each chick was given 0.1 cc. of the bacterial suspension per orem. During the first seven days after exposure no symptoms were observed, and there was no mortality. It was deemed advisable at this time to expose the chicks a second time in order that positive isolation might be obtained. Hence, a second dose (0.5 cc.) of a suspension similar to the first was administered subcutaneously. In Table 10 are given the results obtained from the two exposures to infection.

TABLE 9.—RESULTS OF FEEDING *S. pullorum* VARIANTS TO YOUNG CHICKS.

Strain No.	Number of Chicks	Number Died	Number Yielding *S. pullorum*	Number Killed	Number Yielding *S. pullorum*	Remarks
11706*	5	2	2	2**	2	Symptoms and lesions observed Typical *S. pullorum* recovered
C	5	0	—	5	0	No lesions observed
D-1	5	1	0	5	1	Few lesions observed
E	5	0	—	5	1	Few lesions observed. The recovered organism resembled the original variant
Uninoculated controls	5	2	0	4	0	No lesions

*Represents a normal strain.

**Unfortunately, one chick from group 11706 escaped to cage D-1 on the day the chicks were necropsied. The organism isolated from Group D-1 resembled 11706 more closely than D-1; hence it may be that the escaped bird was infected with strain 11706 and that all birds in Group D-1 were negative.

It is apparent that a greater mortality was encountered from the smooth typical strains than from the variants. Likewise, the percentage of positive isolations of *S. pullorum* was far greater among the typical strains than among the variants. Among the latter, three strains (C, D-1, and IX-b) failed to produce infection.

Variant B (Table 10) established itself in six of seven chicks. In most instances necrotic foci were observed in the liver of these chicks. Prominent fibrous nodules were detected in the myocardium, wall of the proventriculus, gizzard, and intestine. This type of lesion was observed in one or more organs in every chick inoculated with this strain. *S. pullorum* was isolated from the majority of tissues cultured. In a few instances the colony form on plain meat extract agar revealed a slight tendency toward roughness, but these rough features were more pronounced in cultures isolated on liver infusion agar. (See Figures 31-37, inclusive.) Stained smears prepared from colonies on plain meat extract agar revealed typical cells, while those prepared from liver infusion agar contained markedly pleomorphic types. (See Figures 38-41, inclusive.) The cells were also larger in smears prepared from colonies on liver infusion agar. The results obtained with Variant B clearly show that the organism had lost some of its original features during its passage through the host. However, it also is apparent that the recovered organism is not typical in every respect, as shown by the colonial and cellular morphology.

Variant E (Table 10) was recovered from two chicks. One of these died within twelve hours after inoculation. Upon necropsy no significant gross lesions were observed. The organism was recovered from the liver and spleen. On plain meat extract agar the growth resembled that produced by this organism before injection. On liver infusion agar typical rough growth was detected. (See Figures 42 and 43.)

TABLE 10.—RESULTS OBTAINED WITH CHICKS EXPOSED TO NORMAL AND VARIANT STRAINS OF *S. pullorum*.

Strain No.	Number of Chicks	Chicks Died			Number Killed	Number Yielding *S. pullorum*	Total Per cent Positive
		Number	Days After Exposure	Number Yielding *S. pullorum*			
Variants:							
B	7	0	—	—	7	6	85.71
C	7	1	9	0	6	0	0
D-1	7	0	—	—	7	0	0
E	7	1	8	1	6	1	28.57
VI-a	7	0	—	—	7	1	14.28
IX-b	7	0	—	—	7	0	0
Normal Strains:							
IV	7	0	—	—	7	4	57.12
XIV	7	1 1	10 16	1 1	5	3	71.42
11706	7	1 1 1 2	11 15 16 18	1 1 1 2	2	1	85.71
18292	7	1	15	1	6	6	100.00
Uninoculated controls	12	0	—	—	6*	0	0

*Six control chicks were not destroyed.

Few colonies were isolated from the second chick, all of which appeared atypical in colonial and cellular morphology. (See Figures 44-47, inclusive.)

Variant VI-a was recovered on meat extract agar, and resembled the normal type. Liver infusion agar plates were negative. As stated earlier, this variant does not present a very marked colonial difference from the normal.

Strain IV was recovered from four out of seven chicks. Few gross lesions were observed. In every case the organism was isolated from the spleen, while cultural tests with other tissues were negative in most instances. The colonial and cellular morphology on plain extract agar appeared typical, while on liver infusion agar a rough colony type which contained pleomorphic cells was observed. (See Figures 48-51, inclusive.)

Strain XIV was recovered from five out of seven chicks. Gross lesions were observed in most instances, involving one or more of the following organs:—liver, spleen, and heart. The recovered organism exhibited a smooth colony type on meat extract and liver infusion agars in most instances. This strain, while exhibiting a tendency to vary, generally appears quite typical. (See Figures 52-59, inclusive.)

The chicks infected with Strain 11,706 manifested clinical symptoms of the disease. Upon necropsy extensive lesions were observed, and the organism was recovered from six of the seven chicks. This apparently typical strain seemed to be more pathogenic than the other variants employed. Meat extract agar plates yielded typical growth, while on liver infusion agar a few colonies exhibited surface markings. Smears from the different colonies showed the cells from liver infusion agar cultures to be much larger than those taken from meat extract agar. In some cases the difference was so great that the two cultures might be considered different species. (See Figures 60-63, inclusive.)

Strain 18,292 was recovered from all of the seven infected chicks. Gross lesions, which were quite extensive in some cases, were present in all chicks. The colonial and cellular types were similar to those observed with Strain 11,706.

Antigens prepared from the isolated strains were agglutinated by positive pullorum serum, but not by negative serum. However, four antigens (one prepared from Strain VI-a, and three from Strain XIV) exhibited atypical agglutination.

Blood samples were collected from all killed chicks. Agglutination tests with pullorum antigen produced complete agglutination in dilution of 1:40, and a trace in 1:80.

No. 3. Variant IX-b was passed through five different groups of chicks by serial passage. In the first passage a suspension of the organism with a turbidity equal to tube 2 of McFarland's nephelometer scale was administered per orem on three successive days in the following doses:—0.2 cc., 0.5 cc., and 0.5 cc. The remaining groups of chicks were inoculated subcutaneously with 0.4 cc. of a suspension having the same concentration. The time during which the organism remained in artificial cultivation varied between passages. Between the first and second passages the organism was maintained in fresh egg yolk for twenty days before being re-inoculated. In the remaining passages the primary culture was two to five days old when inoculated. Table 11 shows the results of the serial passage of this strain through chicks. The percentage of recovery of the organism is low in every group except No. III. The organism recovered resembled the original inoculated variant in every case. (See Figures 14 and 15.) Scattered isolated colonies attained a diameter of approximately two centimeters. It appeared as if the freshly isolated culture possessed some growth property which appeared absent in the same variant maintained under continual artificial cultivation. The cellular morphology did not vary to any degree during this series of passages.

TABLE 11.—RESULTS OF SERIAL PASSAGE OF VARIANT IX-B THROUGH CHICKS.

Group	Number of Chicks	Number Killed	Number Showing Lesions	Number Yielding *S. pullorum*	Tissues Yielding *S. pullorum*
I	4	4	2	1	Liver
II	10	10	6	1	Yolk
III	5	5	3	3	Subcutaneous necrotic tissue at site of inoculation
IV	5	5	2	1	Subcutaneous necrotic tissue at site of inoculation
V	4	4	4	1	Subcutaneous necrotic tissue at site of inoculation

It will also be noted in Table 11 that the majority of isolations were made from necrotic tissue located at or near the site of inoculation. The amount of necrotic tissue and local tissue reaction varied greatly in the different chicks. In some instances a proliferation of connective tissue, greatly congested and surrounding the leathery yellowish necrotic material, was observed. In two instances the organism invaded the tissues of the host beyond the point of inoculation. However, it was apparent that the invasive power of the organism was not great, although it evidently possessed some power of stimulating a local tissue reaction, which was entirely absent in chicks inoculated with other variants.

These results definitely show that Variant IX-b can invade the natural host beyond the point of inoculation, as well as cause local tissue response without undergoing an alteration in colonial and cellular morphology. Furthermore, little or no increase in virulence was observed. However, this conclusion may not be justified since the experiment was not designed for such a determination.

No. 4. Ten chicks were inoculated subcutaneously with 0.4 cc. of a suspension of Variant XII-b. No mortality resulted from the injection. The variant strain was recovered from three of the killed chicks. In two instances the organism was isolated from the yolk, and in the third, from the spleen, which indicates that the organism had definitely invaded the host and established itself. A marked thickening of the yolk capsule, due to infection, was observed. The isolated organism resembled the original variant in colonial and cellular morphology. (See Figures 18, 64 and 65.) In only one instance was local tissue response evident at the time of necropsy. Variant XII-b is characterized by the filamentous portion of its colony, and this feature apparently is little affected through animal passage.

No. 5. Twelve pullets which were approximately four months of age were inoculated subcutaneously with suspensions of eight variants (A, B, C, D-1, E, VI-a, VIII-a, and IX-a) and four so-called normal strains (IV, XIV, 11,706, and 18,292). Three injections of 2 cc. each were administered on alternate days. Approximately three weeks after the last injection, all birds were necropsied. No clinical manifestations were observed as the result of the inoculation. Table 12 shows the response of the different strains in the living host. Five birds inoculated with variants failed to produce agglutinins. Also, the organism was not recovered at necropsy. Two birds inoculated with typical strains did not yield *S. pullorum* at necropsy, but their sera agglutinated pullorum antigen. Three variants (C, D-1, and E) and two so-called normal strains (XIV and 18,292) were recovered from the birds. The different variants did not lose their characteristic features to any extent, as the result of passage through the host. (See Figures 66-68, inclusive.) Strain XIV exhibited typical colonial features, but the cells appeared pleomorphic in smears prepared from meat extract and liver infusion agar. Antigens prepared from the isolated organisms all exhibited atypical reactions, with the exception of that prepared from Strain 18,292.

S. pullorum was observed in stained tissue impression smears from chicks and adults that yielded pure cultures of the organism on necropsy. The morphology of the organism in a few instances appeared atypical and slightly larger than the normal type, but as a rule a very close resemblance was seen. (See Figures 69-74, inclusive.) Extreme pleomorphic forms were never detected, and it is doubtful whether such forms ever occur in the natural host. However, organisms which possess the potentialities of reproducing pleomorphic types on artificial medium do exist, as has been reported.

In a brief summary concerning the data presented in the different experiments of this part, it may be stated that variants of *S. pullorum* may settle out in broth cultures, but that the degree of settling will vary among the different variants. Likewise, the stability in NaCl solution will vary among different types, and even fluctuate within the same type. The ability to attack different fermentable substances appears to be changed but little, if any, for all variants. Sojourn in fresh whole eggs and in the natural host apparently had little or no influence on the general features of the different variants.

TABLE 12.—RESULTS OBTAINED WITH PULLETS INOCULATED WITH NORMAL AND VARIANT STRAINS OF *S. pullorum*.

Strain No	Bird No.	Days Between Last Injection and Test	Agglutination Titre								Tissues Yielding *S. pullorum*
			10	20	40	80	160	320	640	1280	
Variant:											
A	39391	6	0	0	0	0	0	0	0	0	None
		21	0	0	0	0	0	0	0	0	
B	39386	6	0	0	0	0	0	0	0	0	None
		22	0	0	0	0	0	0	0	0	
D-1	39394	7	4	4	4	2	1	0	0	0	Necrotic cyst in abdominal wall
		20	4	3	1	0	0	0	0	0	
C	39389	7	0	0	0	0	0	0	0	0	Ovary
		20	4	4	4	4	3	2	1	0	
E	39374	7	4	4	4	2	1	0	0	0	Necrotic tissue in abdominal fat
		23	3	2	0	0	0	0	0	0	
VI-a	39390	7	0	0	0	0	0	0	0	0	None
		20	0	0	0	0	0	0	0	0	
VIII-a	39387	7	0	0	0	0	0	0	0	0	None
		20	0	0	0	0	0	0	0	0	
IX-a	39371	7	2	0	0	0	0	0	0	0	None
		20	0	0	0	0	0	0	0	0	
Normal:											
IV	39380	4	4	4	4	4	4	2	1	0	None
		21	4	4	4	4	2	0	0	0	
XIV	39383	6	4	4	2	0	0	0	0	0	Ovary and spleen
		21	3	2	1	0	0	0	0	0	
18292	39381	5	4	4	4	4	4	2	1	0	Heart, spleen and ovary
		21	4	4	4	4	3	1	0	0	
11706	39373	4	4	4	4	4	4	2	0	0	None
		20	4	4	4	4	3	0	0	0	

Legend: 4—complete agglutination
3—incomplete agglutination
2—partial agglutination
1—slight agglutination
0—no agglutination

VIRULENCE STUDIES

The virulence of pathogenic bacteria has been known to fluctuate since the discovery of human and animal pathogens. A decrease or loss of virulence is frequently observed among laboratory strains that are cultivated on artificial media. Also, it has been claimed that fluctuations in epidemics and epizootics are in part due to a variation in the virulence of the causative agent. However, direct and conclusive evidence to support such a statement is wanting at the present time. It is accepted that avirulent strains may be isolated simultaneously with highly virulent types from the same natural outbreak. The virulence of pathogens may be attenuated by various means such as the application of antiseptics, drugs, heat, body fluids, etc. Furthermore, diminished or complete loss of virulence is frequently associated with a variation of the other properties of a microorganism, such as colony and cellular form, antigenicity, and agglutinability. Arkwright (1921), De Kruif (1921), and others have demonstrated that certain types may possess different degrees of pathogenicity. In order to determine the virulence possessed by the different variants described in this investigation, some of the types were studied in the natural host and in an alien host (guinea pig).

For convenience in the exposition of the results obtained in this phase of the investigation, the virulence studies concerning the natural host are presented first.

Pathogenicity for the Natural Host

A total of 312 day-old chicks and 19 different strains of *S. pullorum* (including variants and their parent strains) were employed. The various strains were studied in small lots of chicks. Comparative virulence tests were made with the parent strain and its variant in every lot of chicks except one. The chicks were maintained under the best possible sanitary conditions and were given ample food and water. Necessary heat was provided by improvised means. Every possible precaution was taken to eliminate cross-infection, and proved effective, as will be seen later. The procedure of infecting the chicks was in general the same throughout this investigation. Previous experiments made it seem advisable to select an inoculating dose that would produce positive results with the parent strains. Hence, a dose of 0.4 cc. of a saline suspension of the organism, with a turbidity equal to tube 2 of McFarland's nephelometer scale, was inoculated subcutaneously in the region of the loose skin between the thigh and abdomen. The suspended organisms were prepared from 24-hour agar cultures. Under natural conditions it has been observed that the onset and course of a disease outbreak may be greatly influenced if the resistance of the host is lowered by overheating, chilling, or improper feeding. In order to further insure the establishment of infection, the different lots of chicks were chilled immediately after inoculation. The chilling temperature and the time of exposure were not the same for all groups of chicks. However, the chicks within the same lot were subjected to the same treatment, unless otherwise stated. Clinical manifestations were recorded and all dead chicks were necropsied. *S. pullorum* cultures were identified by the cultural, tinctorial, and biochemical properties. Two weeks after the inoculation the surviving chicks were destroyed and necropsied. The results obtained are presented in Table 13.

Brief supplementary remarks may be made for each lot of chicks as follows:—

Lot I. The chicks in this group were not chilled. No clinical manifestations were observed. A similarity in the degree of virulence between Variant C and its parent Strain I may in part be accounted for by Strain I having been subjected to various treatments since the time of isolation, and having at times exhibited characteristics remote from the typical smooth type.

Lot II. Ten chicks, five of which were chilled, were inoculated with parent Strain IX. Symptoms were observed in both the chilled and unchilled chicks. Extensive gross lesions were observed in most cases, and a marked local tissue response was seen at the site of inoculation. The latter was absent in the chicks inoculated with variant IX-a.

Lot III. The same parent strain as in Lot II, and its variant IX-b, which was maintained on liver infusion agar, were employed. Also, a strain (Stellar) which was freshly isolated from naturally infected chicks was included. During the chilling process two chicks were lost from each of the groups inoculated with Strains IX and IX-b. No clinical response was seen in chicks inoculated with the variant, while in the other two groups marked reactions were observed in some chicks. The lesions in the latter two groups were more extensive than in the group inoculated with the variant. The organisms recovered resembled the original inoculated strains. The variant grew profusely and the colonies attained a diameter of one centimeter.

TABLE 13.—RESULTS OBTAINED WITH CHICKS INOCULATED WITH THE NORMAL PARENT STRAINS OF *S. pullorum* AND THEIR VARIANTS.

Lot No.	Strain No.*	Number of Chicks	Number Died	Number Yielding *S. pullorum*	Number Killed	Number Yielding *S. pullorum*	Total Per cent Positive	Remarks
I	**I (not chilled)	10	0	—	10	0	0	No significant gross lesions
	C (not chilled)	10	0	—	10	0	0	No significant gross lesions
	Controls (not chilled)	6	0	—	6	0	0	No gross lesions observed
II	**IX (not chilled)	5	1	1	4	4	100.00	All chicks revealed gross lesions
	**IX	5	0	—	5	5	100.00	All chicks revealed gross lesions
	IX-a	10	0	—	10	0	0	No gross lesions observed
	Controls	6	0	—	6	0	0	No gross lesions observed
III	**IX	10	3	3	5	5	100.00	All chicks revealed gross lesions
	IX-b	10	0	—	8	4	50.00	Five chicks revealed gross lesions
	Stellar	10	3	2	7	7	90.00	All chicks revealed gross lesions
	Controls	6	0	—	6	0	0	No gross lesions observed
IV	**I	5	0	—	5	0	0	No gross lesions observed
	C	5	0	—	5	0	0	No gross lesions observed
	**XIV	5	1	1	4	4	100.00	All revealed gross lesions
	E	5	2	2	3	3	100.00	All revealed gross lesions
	Controls	5	0	—	5	0	0	No gross lesions observed
V	B	10	0	—	10	0	0	No gross lesions observed
	B-1	10	0	—	10	0	0	No gross lesions observed
	Controls	7	0	—	7	0	0	No gross lesions observed
VI	**VIII	10	10	10	0	–	100.00	All chicks revealed extensive gross lesions
	VIII-a	10	2	—	8	0	0	One chick revealed gross lesions
	Controls	6	0	—	6	0	0	No gross lesions observed
VII	**III	10	10	9	0	–	90.00	All chicks revealed gross lesions
	III-a	10	1	0	9	0	0	One chick revealed gross lesions
	III-S	10	8	8	2	2	100.00	All chicks revealed gross lesions
	Controls	5	0	—	5	0	0	No gross lesions observed
VIII	**VIII	5	2	2	3	2	80.00	All chicks revealed gross lesions
	**VIII (diluted)	5	2	2	3	3	100.00	All chicks revealed gross lesions
	VIII-a	10	0	—	10	0	0	No gross lesions observed
	VIII-a†	5	0	—	5	0	0	No significant gross lesions observed
	III-a†	5	0	—	5	0	0	One chick revealed gross lesions
	Controls	6	1	0	5	0	0	No gross lesions observed
IX	**XII	10	6	6	4	4	100.00	All chicks revealed gross lesions
	XII-a	10	0	—	10	3	30.00	Four chicks revealed gross lesions
	XII-b	10	0	—	10	3	30.00	Two chicks revealed gross lesions
	Controls	5	1	0	4	0	0	No significant gross lesions observed
X	**XII	10	10	10	0	–	100.00	All chicks revealed gross lesions
	XII-a	10	0	—	10	2	20.00	Three chicks revealed gross lesions
	XII-S	10	0	—	10	4	40.00	Three chicks revealed gross lesions
XI	VIII-a††	10	0	—	10	2	20.00	Three chicks revealed gross lesions

*Refer to Table 4 for history of strains.
**Represents parent strain.

†Chicks received five daily inoculations.
††Chicks received fourteen daily inoculations.

Lot IV. The chicks inoculated with Strain I and its variant C responded in the same manner as those in Lot I, in spite of the fact that they had been chilled while those in Lot I had not. It appears that these two strains, as employed here, might be considered avirulent. Strain XIV and its variant E behaved similarly, although the parent strain appeared slightly more virulent. However, this difference may not be significant, since the clinical and pathological manifestations may be due in part to other factors, aside from virulence. The strains isolated resembled the original inoculated type.

Lot V. The strains employed in this lot produced negative results in every respect. As a matter of interest, ten chicks from this lot were inoculated with variant XII-b. Positive isolations of this variant were obtained. (These results are reported in Experiment 4, page 39.)

The chicks employed in subsequent lots were received from a different source. Unfortunately, one infected adult bird was detected in the parent stock from which the chicks in the previous experiments were obtained. This flock had not harbored birds reacting to the macroscopic agglutination test, for three years. However, the chicks received from this flock did not represent the progeny of the infected bird or birds that were in contact with the latter, and it appears from the results that the chicks employed undoubtedly were free from the disease.

Lot VI. Most striking results were obtained with the strains in this group. Strain VIII was observed to be markedly virulent, as compared to its variant and other strains employed previously. All chicks died within two days after inoculation. No symptoms were observed in the chicks that were inoculated with the variant.

Lot VII. In this group the type of variant was similar to VIII-a used in Lot VI. Strain III-S represents a typically smooth strain selected from the same "SR" culture from which III-a was derived. Strain III-S had been treated in the same manner as III-a and was included in this lot to determine whether the decrease or loss in virulence might be due to the treatment of the organism which affected virulence only, or whether the difference in colonial appearance represented certain profound changes in the organism which also influence virulence. It was observed that the symptoms, mortality rate, and lesions were quite similar for Strains III and III-S. One chick inoculated with III-a died from overcrowding.

Lot VIII. In this lot an effort was made to determine the influence of diluting the concentration of the dose used for inoculation. The parent strain was prepared in two different concentrations, the one equal to the usual turbidity employed, and the other diluted three times. It may be observed that there were no noticeable differences in the results of the inoculations. Also, two groups of five chicks each were inoculated with Variants VIII-a and III-a, respectively, for five consecutive days. No symptoms were detected in the chicks inoculated with the variants.

Lot IX. Two variants derived from one and the same strain were employed in this lot. The parent strain caused mortality, and the number of positive isolations of this strain was greater than that of the variants. Variant XII-a was isolated as typical *S. pullorum*, but XII-b was recovered with apparently little or no change in colonial and cellular morphology. (See Figures 18, 64, and 65.)

Lot X. In this group XII-S was a smooth strain which was derived from XII-a ten days prior to inoculation. While the difference in symptoms, mortality, and lesions between the parent strain and the two variants is marked, the two variants behaved quite similarly. It appears that, although the property of smoothness had returned, the virulent property of the parent strain had not been restored.

Strain XII-a was recovered, and the growth resembled that of the original variant type. (See Figures 17 and 75.)

Lot XI. The chicks in this group were inoculated with variant VIII-a. A dose of 0.4 cc. was administered daily for the first seven days and 0.5 cc. for the next seven days. No apparent symptoms were observed. Necropsies were conducted one week after the last injection. Two chicks yielded *S. pullorum.* The organism appeared typical (normal) and in no way resembled the variant originally inoculated. In one instance the organism was isolated from the spleen and necrotic tissue at the site of inoculation, while in the other it was isolated only from the necrotic tissue. Lesions in the remaining chicks were of no significance. The recovered organism underwent characteristic agglutination with positive pullorum serum, while with negative serum no agglutination or settling was seen. The serum of the chicks was tested with the homologous antigen and with typical pullorum antigen. The homologous antigen (VIII-a) revealed a tendency to settle out in the first few dilutions, while no agglutination or settling was observed with the pullorum antigen.

TABLE 14.—COMPARISON OF RESULTS OF INOCULATION WITH PARENT AND VARIANT STRAINS OF *S. pullorum.*

Treatment	Number of Chicks	Chicks Died		Chicks Yielding *S. pullorum*	
		Number	Per cent	Number	Per cent
Inoculated with Parent Strain . .	120	48	40.00	90	75.00
Inoculated with Variant........	130	5	3.85	21	16.15
Controls, not Inoculated.......	52	2	3.84	0	0

Table 14 gives a comparison of the results obtained with parent strains and their variants, when inoculated into chicks. Among the 120 chicks inoculated with the parent strains, 48, or 40 per cent, died. Among the 130 inoculated with the variants, 5, or 3.85 per cent, died. *S. pullorum* was isolated from 90, or 75 per cent, of the chicks inoculated with the parent strains as compared with 21, or 16.15 per cent, of those injected with the variants. The differences between the two groups in the percentage of mortality and positive isolations are very significant.

Beyond a doubt, some of the variants studied here definitely appear less pathogenic for chicks than their parent strains. Variants III-a and VIII-a, which were administered in frequent doses without producing symptoms, must have undergone a profound change in their structure, since their parent strains were among the most pathogenic of the strains studied. Relative to the two positive isolations from chicks in Lot XI, one may question whether some of the cell variants reverted to the normal type, or whether the strain was not a pure variant, and contained a few normal cells which, upon repeated injection, gradually established themselves as a so-called typical strain. The author is inclined to subscribe to the latter view, although this is still a matter of speculation, since it is impossible to follow the cell progeny of a mass culture.

It appears that repeated injection of a variant is a means of determining the purity of such a type. As is shown in Table 13, types III-a and VIII-a failed to establish themselves in chicks after five inoculations, but after 14 inoculations of Strain VIII-a positive results were obtained. The fact that this variant was inoculated into the natural host may also account in part for the positive results. Thus, before designating a strain as a pure variant, it would seem advisable to subject the variant to such a selective test or process as would eliminate the weaker organism (the variant) and permit the stronger organism (the normal) to survive.

The results also suggest that all true variants possess a low degree of virulence, or none at all. Strain E apparently seems to be as pathogenic as its parent Strain XIV, which at times was in all probability a variant. Plastridge and Rettger (1930) (1934) have clearly demonstrated that variants may be extremely virulent. Such types, although apparently rare, are very baffling to the diagnostician and difficult to identify, especially to one who has not before encountered such types.

Pathogenicity for an Alien Host (Guinea Pig)

In the study of the behavior of *S. pullorum* in the guinea pig, 10 strains (four parent, five variants, and one apparently normal strain derived from a variant) and 32 guinea pigs were employed. Each strain was inoculated intraperitoneally into three pigs, with the exception of Strain I, which was given to five pigs. All pigs received 0.5 cc. of a suspension of the organism having a turbidity equal to that of tube 2 of the McFarland nephelometer, except animals 43, 44, and 45, which received a concentration equal in turbidity to that of tube 1. The pigs inoculated with the same strain were confined in one cage.

Preliminary experiments revealed that typical normal strains of *S. pullorum* would produce marked symptoms and even immediate death after one or more inoculations, while the variants produced no ill effects. Therefore, antigens with a greater concentration of organisms than previously employed were inoculated. A series of six daily doses was administered to each pig, unless otherwise stated.

The results of this experiment are in part briefly summarized in Table 15. It may be seen that all of the normal strains and one variant produced a symptomatology which was quite similar for all groups. However, the time of response to the inoculation varied greatly, as is revealed by pig 40, which appeared sick on the second day after the first inoculation, and pig 39, which exhibited clinical manifestations on the tenth day. The number of inoculations was guided by the condition of the animal. Among the animals exhibiting symptoms only a few did not succumb. Three pigs (numbers 16, 17, and 43) died following cardiac bleeding, on the twelfth day. *S. pullorum* was recovered from 12 of the 17 pigs (one not cultured) inoculated with apparently typical strains, while no positive isolations were obtained from the pigs inoculated with the variants. Sera were tested for the presence of agglutinins in only 21 animals, since the remainder of the group died as the result of the infection. Agglutinins were detected in two sera, both obtained from pigs inoculated with a normal strain. It is of considerable interest to note that the strain recovered from chicks in Lot XI and designated as VIII-c in Table 15 behaved in a manner similar to the original normal type Strain VIII when inoculated into guinea pigs. These observations point out that virulence can be grossly masked or hidden in a culture that may be a variant with respect to one or more of its characters, but through proper treatment of the variant the virulent types may manifest themselves.

Recognizing the fact that the number of pigs employed for each strain was small, a second experiment was conducted by inoculating one parent strain (VIII) and its variant (VIII-a) each into 14 guinea pigs. The procedure was quite similar to that of the previous experiment. Table 16 shows that the results in the main substantiated previous observations. It is clearly evident that the variants used in the guinea pig inoculations did not possess the invasive power of their parent strains.

TABLE 15.—BEHAVIOR OF NORMAL PARENT STRAINS AND THEIR VARIANTS IN GUINEA PIGS.

Strain No.	Pig No.	Number of Injections	Symptomatology	Necropsy Findings		
				Days after First Injection	Isolation of *S. pullorum*	Agglutinin Titre
I	43	5	Inactive, weak and loss of appetite on the 5th day	12	Not cultured	1:80
	44	4	Inactive, weak and loss of appetite on the 4th day; evidence of purulent conjunctivitis	7	Positive	N. T.**
	45	5	Inactive, weak and loss of appetite on the 5th day; evidence of purulent conjunctivitis	9	Positive	N. T.
	46	3	Inactive, weak and loss of appetite on the 8th day; evidence of purulent conjunctivitis	9	Positive	N. T.
	47	3	Inactive, weak and loss of appetite	21	Negative	1:1280
I-a	16	6	No symptoms	12	Not cultured	None
	17	6		12	Negative	None
	18	6		22	Negative	None
VIII	34	4	Inactive, weak and loss of appetite on the 4th day; evidence of purulent conjunctivitis	7	Positive	N. T.
	35	4		6	Positive	N. T.
	36	4		7	Positive	N. T.
VIII-a	4	6	No symptoms	21	Negative	None
	5	6		21	Negative	None
	6	6		21	Negative	None
VIII-c*	40	1	Inactive, weak and loss of appetite on the 2d day	5	Positive	N. T.
	41	4	Inactive, weak and loss of appetite on the 4th day	5	Positive	N. T.
	42	4	Inactive, weak and loss of appetite on the 4th day	7	Positive	N. T.
IX	37	4	Inactive, weak and loss of appetite on the 4th day; evidence of purulent conjunctivitis	7	Positive	N. T.
	38	5	Inactive, weak and loss of appetite on the 9th day	10	Positive	N. T.
	39	5	Inactive, weak and loss of appetite on the 10th day	12	Positive	N. T.
IX-a	7	6	Inactive on the 5th day	21	Negative	None
	8	6		21	Negative	None
	9	6		21	Negative	None
IX-b	10	6	No symptoms	21	Negative	None
	11	6		21	Negative	None
	12	6		21	Negative	None
XVIII	22	6	Inactive on the 6th day	21	Negative	None
	23	6		21	Negative	None
	24	6		21	Negative	None
XVIII-a	1	6	No symptoms	21	Negative	None
	2	6		21	Negative	None
	3	6		21	Negative	None

*Apparently normal strain derived from VIII-a.
**N. T.—no test.

Summarizing briefly, it may be stated that the so-called normal type of *S. pullorum*, as described previously, possesses certain characters that have been lost or modified in the variants derived from the normal parent strains. The marked difference in virulence between the normal and the variant, as revealed in the chick experiment, was also confirmed in the studies with the guinea pigs. The variant was not only less invasive, but also less capable of establishing itself locally in the host than was the parent strain.

TABLE 16.—BEHAVIOR OF STRAIN VIII AND ITS VARIANT VIII-A IN GUINEA PIGS.

Strain No.	Cage No.	Pig No.	Sex	Weight (Grams)	Number of Injections*	Symptomatology	Necropsy Findings: Days after First Injection	Necropsy Findings: Lesions	Necropsy Findings: Isolation of *S. pullorum*	Necropsy Findings: Agglutinin Titre
VIII	I	1	F	729	5	Inactive and gaunt 3 days after the first injection. Inactivity and weakness progressive, resulting in death 8 days after the first inoculation.	8	Acute peritonitis	Positive	N. T.**
		2	F	723	5	Inactivity and dullness during the course of inoculation.	28	None	Negative	1:40
	II	3	F	627	1	Marked weakness and inactivity the 1st day after the first inoculation; slight conjunctivitis; died 2 days after the initial inoculation.	2	Transudative peritonitis; liver and spleen markedly congested.	Positive	N. T.
		4	F	782	5	No symptoms	28	None	Negative	1:40
	III	5	F	680	5	No symptoms	25	Slight peritonitis and congestion of the intestines.	Negative	N. T.
		6	F	689	5	Inactivity and general weakness, associated with purulent conjunctivitis; gradually improved after the 10th day.	28	None	Negative	1:160
	IV	7	M	772	3	Marked weakness and inactivity after the first injection, associated with purulent conjunctivitis on the 2d day. Death occurred on the 4th day.	4	Fibrinous peritonitis and congestion of the liver and spleen.	Positive	N. T.
		8	M	817	1	Very weak and dull expression on the 1st day, followed by death on the 2d day.	2	Transudative peritonitis; liver and spleen markedly congested.	Positive	N. T.
	V	9	M	665	5	Slight dullness on the 3d day.	28	None	Negative	None
		10	M	847	5	No symptoms	28	None	Negative	1:40
	VI	11	M	592	5	No symptoms	28	None	Negative	None
		12	M	627	5	No symptoms	28	None	Negative	1:10
	VII	13	F	1012	5	No symptoms	29	None	Negative	1:40
		14	F	712	5	No symptoms	29	None	Negative	None
VIII-a	VIII	15	F	729	5	No symptoms	30	None	Negative	None
		16	F	754	5	No symptoms	30	None	Negative	None
	IX	17	F	622	5	No symptoms	31	None	Negative	None
		18	F	789	5	No symptoms	31	None	Negative	None
	X	19	F	689	5	No symptoms	30	None	Negative	None
		20	F	682	5	No symptoms	30	None	Negative	None
	XI	21	M	772	5	No symptoms	31	None	Negative	None
		22	M	804	5	No symptoms	31	None	Negative	None
	XII	23	M	784	5	No symptoms	29	None	Negative	None
		24	M	665	5	No symptoms	29	None	Negative	None
	XIII	25	M	622	5	No symptoms	31	None	Negative	None
		26	M	614	5	No symptoms	31	None	Negative	None
	XIV	27	F	1005	5	No symptoms	31	None	Negative	None
		28	F	730	5	No symptoms	31	None	Negative	None

*Injection—0.5 cc.

**N. T.—no test

SEROLOGICAL STUDIES

In the preceding sections it was shown that variation of *S. pullorum* may occur in colonial and cellular morphology, macroscopic appearance in broth medium, stability in saline solution, and virulence. Similar observations have been reported by other investigators for different species of bacteria. Arkwright (1920, 1921), in a study of some of the members of the colon-typhoid-dysentery group, observed that changes in colony form, salt-sensitiveness, and growth in broth may be associated with profound alteration in antigenic structure.Specificity in agglutination was observed for the normal strain, while non-specific agglutination occurred with the variant. The variant might be altered to the extent that it would be agglutinated by immune serum homologous for variants of unrelated species. Peculiar immunizing and agglutinogenic properties have been ascribed to variants by such investigators as Schütze (1921), De Kruif (1921), and Arkwright (1921.).

According to the classification of the antigenic structure of the typhoid-paratyphoid group by Kauffmann (1930) and White (1926), *S. pullorum* contains only a somatic antigen. White (1932, 1933), in his studies concerning different antigenic fractions of the *Salmonella* group, observed that different surface antigens may be lost through bacterial variation.

In these experiments several normal strains and variants were studied as to their serological behavior. This phase of the investigation bears a direct relationship to the routine serological diagnosis of pullorum disease because, as will be pointed out, *S. pullorum* strains can be so altered in their antigenic structure that they lose their power to produce agglutinins in the host and fail to absorb the specific agglutinins.

Realizing that a salt-sensitive variant could not be employed as a satisfactory antigen strain, an effort was made to stabilize it and yet maintain optimum conditions for agglutination. From the literature one may gain the impression that the problem of maintaining variants suspended in saline solution is of minor importance. It is possible that the variants reported by others were of a different character from those dealt with here. Moreover, while variant types that are different as to their salt-sensitiveness do occur, it is also possible that variation may exist in the interpretation of the behavior of variants in salt solution. In the tests conducted with the variants in this study, the author is inclined to believe that in certain instances a combination of agglutination and settling of cells has occurred. It has been reported by some that the phenomenon of self-clumping in salt solution is identical with that of true agglutination which occurs in an agglutinating serum-antigen-saline mixture. It is apparent that some variants will form perceptible clumps in salt solution, but others may settle without perceptible clumping. With either type of variant, when it is placed in contact with agglutinating serum, the reaction may be quite complex and the end result baffling. The question is to what extent the two phenomena are represented.

White (1926) reported that variants can be made stable in salt solution by treating the culture with 95 per cent alcohol. He also stated that the alcoholic extract contains an antigenic substance, which suggests that the variant itself has been deprived of some of its chemical components by the alcohol treatment. To what extent one can proceed in subjecting the organism to extracting agents without depriving it of the essential constituents for true agglutination remains a question.

Four pullorum-disease-free birds which were negative to the macroscopic agglutination test with pullorum antigen were inoculated, one with normal Strain VIII and the three others with Variants C, VIII-a, and IX-b, respectively.

The birds were maintained in separate cages. Each was inoculated intraperitoneally with 0.5 cc. of a saline suspension of the organism having a turbidity equal to tube 2 of McFarland's nephelometer. Their sera were tested at frequent intervals with known pullorum antigen, and in some instances with an antigen prepared from Strain VIII, which represents the parent strain of variant VIII-a. (See Table 4.) In Table 17 are given the reactions of the different sera with known pullorum antigen and with their homologous antigens nine days after the first injection of the different strains. It will be seen that only one serum (Bird 3) produced with the typical strain reacted with pullorum antigen. The reaction appeared similar to that produced with the homologous antigen. The reaction between the serum of Bird 1 and its homologous antigen (C) did not appear as typical agglutination in the lower dilutions, and in the higher dilutions the character of the settling was the same as in the antigen control. A similar observation was made with the serum of Bird 4, while the serum of Bird 2 did not react with its homologous antigen. It appears from these results that the three variants employed do not possess antigenic power equal to that of the typical normal strain.

TABLE 17.—AGGLUTINATION TITRES OF SERA TESTED WITH HOMOLOGOUS AND HETEROLOGOUS *S. pullorum* ANTIGEN.

Bird No.	Antigen	Agglutination Titre								Antigen Control	Serum Control
		10	20	40	80	160	320	640	1280		
1	Pullorum	0	0	0	0	0	0	0	0	0	0
	C*	?	?	?	?	?	S	S	S	S	
2	Pullorum	?	?	0	0	0	0	0	0	0	0
	IX-b*	S	S	S	S	S	S	S	S	S	
3	Pullorum	4	4	4	4	4	4	4	2	0	0
	VIII**	4	4	4	4	4	4	4	3	0	
4	Pullorum	0	0	0	0	0	0	0	0	0	0
	VIII-a*	?	?	?	S	S	S	S	S	S	

*Variants
**Normal strain
Legend: 4—complete agglutination
3—incomplete agglutination
2—partial agglutination
1—slight agglutination
0—no agglutination
?—not typical agglutination
S—settling of cells

In a second experiment Strain VIII and its variant VIII-a were inoculated into three and five mature birds, respectively. Each bird was inoculated intraperitoneally with 2 cc. of live antigen, with a turbidity equal to that of tube 2 of McFarland's nephelometer. Six consecutive daily doses were administered to each bird, except the birds inoculated with the variant, which received seven consecutive daily doses approximately one month after the first inoculation. Table 18 shows that the three birds injected with the normal strain developed a titre within eight days after the first inoculation, while the birds receiving the variant gave no agglutinin response until after the second series of inoculations. Furthermore, the agglutinin response observed in the birds receiving the variant was extremely feeble. All birds were necropsied at the end of a period of 190 days. While the titres at necropsy were considerably lower than those observed earlier, the decrease in titre does not necessarily mean freedom from infection, since *S. pullorum* was recovered from Bird 18950, which possessed a titre of 1:20.

TABLE 18.—BEHAVIOR OF A PARENT NORMAL STRAIN (VIII) AND ITS VARIANT (VIII-A) IN THE NATURAL ADULT HOST.

Strain No.	Bird No.	Number of Injections	Agglutinin Titre (Days after First Injection)													Necropsy Findings	Isolation of *S. pullorum*
			8	12	19	28	33	40	47	54	69	82	97	124	190		
VIII	18950	6	80	1280	2560	—	—	640	—	320	320	160	160	80	20	Neoplastic invasion (sarcomatous in nature) of the heart muscle, kidney, liver, and spleen. A cyst (2 cm. in size) was attached to the gizzard. Contents consisted of yellow cheesy material and amber oily fluid. *S. pullorum* isolated only from the cyst contents.	Positive
	19018	6	320	1280+	5120	—	—	2560	—	640	640	320	320	320	160	No gross lesions	Negative
	19050	6	5120	2560	1280	—	—	160	—	40	20	40	20	20	40	No gross lesions	Negative
VIII-a	18882	13	0	0	0	0	20	20	10	0	0	0	0	10	0	Adhesions of the visceral peritoneum. Few small cysts embedded in abdominal fat.	Negative
	18989	13	0	0	0	0	20	10	10	0	0	0	0	10	0	No gross lesions	Negative
	19002	13	0	0	0	0	20	40	10	10	0	10	0	10	20	Cyst (2 mm. in size) free in abdominal fat. One misshapen cystic ovum (1.5 cm. in size).	Negative
	19042	13	0	0	0	0	10	10	10	10	0	10	0	10	20	No gross lesions	Negative
	19049	13	0	0	0	0	40	0	10	10	0	0	0	0	10	No gross lesions	Negative

These results conclusively show that the variant VIII-a does not possess the power to stimulate agglutinin production in the living natural host to the extent that its parent strain does. Also, it failed to establish itself in the natural host.

The absorptive capacities of several normal strains and their variants were determined. In preliminary studies natural, positive pullorum serum and a homologous chicken serum for Strain VIII were employed. Strain VIII and its variant VIII-a were used for the absorbing organisms. The unabsorbed and absorbed sera were tested with known pullorum antigen and with antigen prepared for Strain VIII. The results in Table 19 show that the typical strain, VIII, was capable of absorbing all of the agglutinins from its homologous serum and from the natural serum, while variant VIII-a reduced the titre to a lesser degree.

TABLE 19.—RESULTS OF AGGLUTININ ABSORPTION.

Serum	Serum Titre					
	Before Absorption		After Absorption with VIII		After Absorption with VIII-a	
	Antigen (Pullorum)	Antigen VIII	Antigen (Pullorum)	Antigen VIII	Antigen (Pullorum)	Antigen VIII
Pullorum	640	1280	0	0	640	160
No. 3	1280	2560	0	0	640	640

In the determination of the absorptive capacities of the different parent strain and their variants, five sera which varied in titre were employed. The sera were tested with a stock antigen before and after absorption to determine the reduction in titre. The absorbing antigens were prepared from either a 24- or 48-hour growth, depending upon the yield obtained. The different sera were absorbed with a live antigen which had a turbidity equal to tube 8 of McFarland's nephelometer. However, in some cases a less dense suspension was found satisfactory to bring about complete absorption. Some sera were absorbed three times, others twice, depending upon the agglutinin titre and the absorbing power of the strain. The serum and antigen dilution employed during absorption was 1:10. Twelve original parent strains (I, II, III, VI, VIII, IX, XII, XIII, XIV, XVI, XVIII, and I (Experiment I)) and 16 variants (I-a, II-a, III-a, VI-a, VIII-a, IX-a, IX-b, XII-a, XII-b, XIII-a, XVI-a, XVIII-a, A, A-1, C and E, and four miscellaneous strains) were studied. Since the results in general are very much the same in the two groups (parent and variant) only one set of data is presented in Table 20. It may be seen in the table that the variant does not possess the absorptive capacity of its parent strain.

TABLE 20.—COMPARATIVE RESULTS IN AGGLUTININ ABSORPTION WITH PARENT STRAIN IX AND ITS VARIANT IX-A.

Test Antigen	Sera	Titre before Absorption										Titre after Absorption	
		20	40	80	160	320	640	1280	2560	5120	10,240	With Strain IX	With Variant IX-a
Regular Stock Antigen	A	4	4	4	4	3	1	0				0	640
	B	4	4	4	4	4	4	3	2	1	0	0	10,240
	C	4	4	4	2	1	0					0	320
	D	4	4	4	4	4	4	3	2	1	0	0	5,120
	E	4	4	4	4	4	4	4	3	2	1	0	10,240

Strain XIV exhibited only slight absorption, while Strain I, Experiment I, caused no reduction in agglutinin titre. The variants derived from these strains behaved in a like manner. Variants XII-a and XII-b exhibited absorptive ability, but not to the same degree; only the latter completely absorbed the agglutinin content. No definite explanation is offered for this difference in action, except that the one variant possessed a sufficient number of the cell type which was capable of absorbing the agglutinins. The fact that this variant produced two types of cells in its colony structure (See Figures 18, 19, and 20), makes it quite possible that the more typical appearing cell was present in sufficient quantity to bring about complete absorption.

The four miscellaneous strains, which appeared typical, had been subjected to treatment similar to that of the variants, but did not change in colonial and cellular morphology. Likewise, their capacity to absorb agglutinins was as great as that of the original parent strain.

These results show that variants which yield different colonial and cellular forms, which are different from the original strain, also possess little or no power for absorbing specific agglutinins.

DISCUSSION

A review of the literature shows that bacterial variation of *S. pullorum* has been observed and studied by only a few investigators. Mallmann (1932) worked principally with strains that had been maintained under laboratory conditions for a period of time varying from four to nine years. The impression is given that variants are seldom isolated from natural outbreaks of the disease. The criterion used for the variant study seemed to include only a change in colony morphology. On the other hand, Plastridge and Rettger (1930) reported a natural outbreak of the disease among young and adult stock from which pleomorphic types were isolated. These types appeared strikingly different from the normal type in several respects.

Since so few observations have been reported concerning the incidence of *S. pullorum* variants among freshly isolated strains, the writer believed that an examination of a large number of recently isolated strains might yield valuable additional information. It was realized from the first that a change in colony form was not the only feature that would classify a strain as a variant or normal type. If the colony type had been selected as the only means of identifying variants, all but two of the strains studied by the writer would have been designated as typical. Likewise, if these strains had been identified only by the Gram-stain method and biochemical reactions, all would have been considered typical. Hence, to classify an organism as typical, its various properties must be studied. Furthermore, only slight deviations, which might be overlooked by one not familiar with the characteristics of variants, may be observed at times. The property of salt-sensitiveness would in all probability be overlooked when the rapid serum agglutination method is employed to determine the agglutinability of a freshly isolated strain. While this method may have its merits in the diagnosis of pullorum disease, it should not be abused by being employed for the typing of the organism unless every step is carefully controlled.

The source of the strain apparently cannot be correlated with the incidence of variants, since the different types were isolated from eggs, chicks, and adult fowl. However, if a large number of cultures from one source were examined, it might be possible to show such a correlation. Strange as it may seem, in the routine testing of domestic fowl re-infected flocks generally show a very small number of infected birds, often as few as one. Cultures obtained from adult birds and studied in this investigation represent positive isolations from flocks revealing only one infected bird. Some of these infected individuals possessed very low agglutinin titres, which may be due in part to the organism. In order to obtain more evidence which might serve to explain the relation of bacterial variation to flocks revealing one or more infected birds, a specially designed project seems necessary.

Environment and Bacteria

The placing of bacteria under different environmental conditions may bring about many types of variation in the organism. The observations reported in this investigation are in general agreement with those reported for other organisms. While it may be true that *S. pullorum* is quite stable when maintained under uniform and constant laboratory conditions, under certain influences such as described earlier, the organism may undergo profound changes. The majority of strains studied were susceptible to marked variation. It was impossible to study slight variation simultaneously with extreme changes, but the author feels that this phase is probably of great practical importance. Slight variations from the normal type are more difficult to detect, and they may be induced by unfavorable environment. Various strains will respond differently to the same environment. This has been observed when strains were streaked on liver infusion agar. Differences in colony and cellular morphology may be noted. This also holds true for agar medium prepared from different livers. Liver medium may serve to bring out variation tendencies that otherwise might remain obscure. The results suggest that continuous cultivation of *S. pullorum* on liver infusion medium is more liable to bring about a change in the organism than growth on plain meat extract agar.

The relation of one colony type to another cannot be explained with any degree of satisfaction. It appears that certain types are more remote from the parent strain than others, but this may be applicable only to one or more features, such as colony form, virulence, and antigenic structure. To classify all of the different variants as to their order of development or degree of variation does not seem possible at this time. The realm of variation may possess great latitude. The border between normal and variant types should not be looked upon as a sharp line of demarcation. A normal type may vary in some of its aspects, but the changes may not be perceptible. Furthermore, a normal type may lose one property which is replaced by another characteristic as, for example, smoothness for roughness in colony surface. The change from the smooth to the rough character may extend over a wide range of colony types. Also, a character may completely disappear without the acquisition of a new property, as, for example, the loss of ability to ferment a certain carbohydrate. Additional properties may be acquired without previously having lost a character, as is the case with the maltose fermenting strain included in this investigation. One and the same type of variant may appear different on two kinds of media. Variants may fluctuate in their colonial and cellular types. Colonies that consist largely of the filamentous forms are the most difficult to propagate and to maintain as stable. However, Variant XII-b, which produces a filamentous type of colony, has remained very stable and uniform in its features.

The terms "S" and "R" introduced by Arkwright for smooth and rough forms seem most inappropriate, because variants may be observed which have a smooth surface and yet are far remote from the parent strains in antigenic structure. The correlation between colonial form and antigenic structure is by no means constant. This also applies to other features.

Since our knowledge concerning the underlying causes that bring about these changes from the normal to the variant is meagre, it is apparent that a greater insight with respect to the physiology and chemistry of the microorganism is needed.

Behavior of Variants

According to the results obtained in the preceding experiments, variants may differ greatly when placed under certain conditions. The phenomenon of clumping, settling, and clearing of broth cultures was reported by Nicolle in 1898. Other investigators have also made this observation, but Arkwright (1920) associated this feature with other distinguishing characters, such as change in colony form and serological properties. While this view may be correct for certain variants, for others it does not seem to hold. The mechanism that is operating when organisms settle out in broth is little understood. The fact that variants may or may not exhibit this phenomenon indicates that it cannot be employed as a general criterion for all variants.

Salt-sensitiveness has also been designated as a means of detecting variants. Certain variants studied in this investigation exhibited this property, but the degree of instability in salt-solution did not appear to be constant. The degree of roughness of the colony type could not be correlated with the degree of salt-sensitivity. The reaction of auto-flocculating or settling was always completed within 24 hours. As the salt concentration was reduced the stability of the organism was increased. However, not all variants responded alike to diminished salt concentration.

The ability of the different variants to attack various fermentable substances was practically comparable to that of normal types.

In some cases the character of the growth was markedly influenced by the acidity and possibly other environmental factors. The extreme variation in some of the characteristics had little or no influence on the fermentative property. That *S. pullorum* may acquire or reveal the property to ferment substances in addition to those that are attacked by the normal type was observed by the author previously. A maltose-fermenting property was either acquired or revealed which has remained stable for several years. This property may be looked upon as a very unusual characteristic for *S. pullorum*. Investigational results pertaining to this maltose-fermenting strain will appear in detail in another publication.

The cultivation of pathogens in an environment which approaches the natural was undertaken. Beyond a doubt, the most frequent mode of transmission of *S. pullorum* from adult to chick is by means of the egg. Since the egg is frequently a part of the natural environment of the organism, it appeared that it might exert a definite influence on the variants. The egg medium employed in this investigation caused little or no change in the character of the variants. It appears to the author, therefore, that fresh eggs might prove more satisfactory in retaining strains in their original state than the media ordinarily employed.

In the experiment dealing with the passage of the parent type and the variants through the natural host, it was demonstrated that the variants are less invasive than the normal strains. Larger infecting doses than are ordinarily employed with normal strains were necessary to obtain positive infection. Even then some variants failed to establish themselves in the chick or adult bird. In one instance (Variant B) it was demonstrated that partial reversion to the normal type had occurred. This variant was similar in colony morphology to Variant VIII-a which yielded smooth and apparently typical colonies only after a series of injections. With both variants the chicks exhibited no clinical manifestations, but the pathological picture was more extensive in the chicks injected with Variant B than with Variant VIII-a. The smooth type strain (VIII-c) derived from Variant VIII-a through a series of inoculations into baby chicks apparently exhibited the same degree of virulence for guinea pigs as the original parent Strain VIII. That some variants may pass through the host unaltered in some of their characteristics was demonstrated with Strains IX-b and XII-b. It is extremely interesting to note that one may inoculate the natural host with a variant as remote in colony form from the normal type as Variant IX-b and recover the same apparently unchanged.

The presence of the organism in the tissues was detected by tissue smears. The observation of different pleomorphic types of cells outside of the host raised the question of the morphology of the cells when present in the host. It was demonstrated that tissue smears from organs which yielded pure growth on primary culture might not reveal the organism. It was found that the organism most frequently appeared in smears from the yolks of chicks. In this tissue some atypical forms were observed, but for the most part the organisms appeared slightly larger than the normal type isolated on meat extract agar. It does not seem likely that extremely pleomorphic types would be found in body tissues except possibly in tissues such as unabsorbed yolk, where there is a different histological and physiological environment than is found in other parts of the host. Whether the pathological ovary of an adult fowl is conducive to variation is not known, except that the majority of positive isolations originating from this organ seem typical.

The experimental evidence concerning the pathogenicity of the variants definitely suggests that the organisms have become void of some constituent or physiological property that renders them avirulent. Some variants (III-a and VIII-a) that appear markedly different from the normal type on plain agar, seem to possess no invasive power and induce no local tissue response at the site of inoculation. It appears that the defensive power, as well as the aggressive property, has been lost. Such types are not expected to survive in the host for any length of time, even when injected in large doses. Variants that have been developed on liver infusion agar appear to be slightly more aggressive and offer a greater resistance to the defense mechanism of the host than the type represented by III-a and VIII-a. Such types may be encountered under natural conditions. However, the type respresented by Variant E appeared the most virulent of all types isolated. The fact that its parent strain XIV at times revealed tendencies to vary may account for its high degree of virulence. The pleomorphic types described by Plastridge and Rettger possessed a marked invasive and infective power. None of the strains described in this investigation, with the possible exception of strain XIV, approached these types in virulence.

The serological investigations show that the variants underwent a profound change in the antigenic structure, since they were unable to stimulate the production of agglutinins, and also were unable to absorb agglutinins from natural and artificial immune sera. These observations appear very significant. One must assume from them that such profound changes, may occur among stock cultures that are employed for the preparation of antigens used in the macroscopic agglutination test. The degree of sensitivity of an antigen and the type of agglutination may be greatly influenced by the ratio of the variant to the normal type in a mixed population of cells.

SUMMARY AND CONCLUSIONS

From the experimental evidence obtained in the investigation discussed here the following conclusions seem justified.

Variation of characters of *S. pullorum* may be detected among freshly isolated strains, as revealed by 13 of 163 strains studied.

The behavior of the recently isolated variants in sodium chloride solution of different concentrations and in the presence of positive and negative sera differed greatly.

Such properties as colonial and cellular morphology, Gram-staining, and biochemical reactions revealed little or no variation in the majority of the derived variants.

Many strains of *S. pullorum* readily underwent variation when subjected to frequent transfer and storage in meat infusion broth.

Variants were isolated and stabilized on solid media by colony selection and by frequent transfer.

When variants were cultivated on both meat extract agar and liver infusion agar the colonial and cellular features often appeared markedly different. Some strains that appeared typical on meat extract agar exhibited pleomorphic tendencies when placed on liver infusion agar.

Variation of *S. pullorum* was not observed when the organism was subjected to alternate transfer in liquid and solid media, or cultivated in 5 per cent peptone solution, in deep meat infusion broth, or in plain 3 per cent meat extract solution.

S. pullorum variants may settle out in broth cultures, the degree of settling varying with the different types.

The ability to remain suspended in sodium chloride solution varies with the different variants, and it may fluctuate even within the same type.

The power of the variants to attack the different fermentable substances was practically the same as that of the normal type.

Passage of the variants through whole fresh eggs and through the natural host (chicks and mature fowl) had little or no influence on the general features of the different types.

Most variants exhibited a lesser degree of virulence than their parent strains, and in some instances appeared avirulent.

Repeated subcutaneous inoculations of massive doses of variants may serve as a means of detecting organisms that resemble the normal type in colonial and cellular morphology, Gram stain and biochemical reactions, and in agglutinability.

A menstruum which maintained the variants in suspension and which was also satisfactory for conducting the agglutination tests was not discovered.

The agglutinogenic power and the absorptive capacity of the variants tested were not equal to those of the normal type.

BIBLIOGRAPHY

Abbot, A. C. 1912. On induced variations in bacterial functions. An experimental study. Jour. Med. Research 26:513-521.

Arkwright, J. A. 1920. Variation in bacteria in relation to agglutination by salts and by specific sera. Jour. Path. and Bact. 23:358-360.

Arkwright, J. A. 1921. Variation in bacteria in relation to agglutination both by salts and by specific serum. Jour. Path. and Bact. 24:36-60.

Arkwright, J. A. 1924. The source and characteristics of certain cultures sensitive to bacteriophage. Brit. Jour. Expt. Path. 5:23-33.

Arkwright, J. A., and Goyle, A. N. 1924. The relation of the "smooth" and "rough" forms of intestinal bacteria to the "O" and "H" forms of Weil and Felix. Brit. Jour. Expt. Path. 5:104-114.

Arkwright, J. A. 1927. The value of different kinds of antigen in prophylactic "enteric" vaccines. Jour. Path. and Bact. 30:345-364.

Arkwright, J. A. 1930. System of Bacteriology. Medical Research Council (London).

Baerthlein, K. 1912. Untersuchungen über Bact. coli mutabile. Centralbl. Bakt. I Abt., Orig. 66:21-35.

Baerthlein, K. 1918. Ueber bacterielle Variabilität insbesondere so-genannte Bakterienmutationen. Centralbl. Bakt. I Abt., Orig. 81:369-435.

Benians, T. H. C. 1919. A record of an inagglutinable form of Shiga's dysentery bacillus, experimentally derived from an agglutinable culture. Jour. Path. and Bact. 23:171-176.

Buchanan, R. E., and Truax, R. 1910. Non-inheritance of impressed variations in Streptococcus lacticus. Jour. Infect. Diseases 7:680-697.

Burri, R. 1910. Ueber scheinbar plötzliche Neuerwerbung eines bestimmten Gärungsvermögens durch Bakterien der Coligruppe. Centralbl. Bakt. II Abt. 28:321-345.

Chamberlain, Ch., and Roux, E. 1883. Sur l'attenuation de la virulence de la bacteridie charbonneuse, sous l'influence des substances antiseptiques. Compt. Rend. Acad. Sci. [Paris] 96:1088-1991.

Cole, L. J., and Wright, W. N. 1916. Application of the pure-line concept to bacteria. Jour. Infect. Diseases 19:208-221.

Dawson, A. I. 1919. Bacterial variations induced by changes in the composition of culture media. Jour. Bact. 4:133-148.

Dearstyne, R. S., Kaupp, B. F., and Wilfong, H. S. 1929. Study of pullorum disease from a flock standpoint. N. C. Agr. Expt. Sta. Tech. Bul. 36, 53 pp.

De Kruif, P. H. 1921. Dissociation of microbic species. I. Coexistence of individuals of different degrees of virulence in cultures of the bacillus of rabbit septicemia. Jour. Expt. Med. 33:773-789.

Dobell, C. 1912. Some recent work on mutation in microorganisms. II. Mutations in bacteria. Jour. Genetics 2:325-350.

Durham, H. T. 1898. A discussion on the agglutinating or sedimenting properties of serums and their relation to immunity. Brit. Med. Jour. 2:588-592.

Eisenberg, P. 1906. Ueber sekundäre Bakterienkolonieen. Centralbl. Bakt. I Abt., Orig. 40:188-194.

Eisenberg, P. 1912. Untersuchungen über die Variabilität der Bakterien. II. Mitteilung über sogenannte Mutationsvorgänge bei Choleravibrionen. Centralbl. Bakt. I Abt., Orig. 66:1-19.

Eisenberg, P. 1918. Untersuchungen über die Variabilität der Bakterien. VI. Mitteilung: Variabilität in der Typhus-Coli Gruppe. Centralbl. Bakt. I Abt., Orig. 80:385-413.

Enderlein, G. 1925. Bakterien-Cyclogenie. Prologomena zu Untersuchungen über Bau, geschlechtliche und ungeschlechtliche Fortpflanzung und Entwicklung der Bakterien. p-1.

Furth, J., and Landsteiner, K. 1928. On precipitable substances derived from Bacillus typhosus and Bacillus paratyphosus B. Jour. Expt. Med. 47: 171-184.

Goodman, H. H. 1908. Variability in the diphtheria group of bacilli. Jour. Infect. Diseases 5:421-442.

Goyle, A. N. 1927. The effect of heat on the agglutination of bacterial emulsions. Jour. Path. and Bact. 30:331-344.

Gwatkin, R. 1927. Bacteriophage experiments. Ontario Vet. Col. Rpt. 1926:48-58.

Hadley, P. 1927. Microbic dissociation. Jour. Infect. Diseases 40:1-312.

Henry, B. S. 1933. Dissociation in the genus Brucella. Jour. Infect. Diseases 52:374-402.

Hiss, P. H. 1904. On fermentative and agglutinative characters of bacilli of the "dysentery group." Jour. Med. Research 13:1-51.

Horton-Smith, P. 1900. The typhoid bacillus and typhoid fever. (The Gaulstonian Lectures.) Brit. Med. Jour. 2:827-834.

Jacobsen, K. A. 1910. Mitteilungen über einen variablen Typhusstamm (Bacterium typhi mutabile) sowie über eine eigentümliche hemmende Wirkung des gewöhnlichen Agar, verursacht durch Autoklavierung. Centralbl. Bakt. I Abt., Orig. 56:208-216.

Jordan, E. O. 1917. The differentiation of the paratyphoid-enteritidis group I. Jour. Infect. Diseases 20:457-484.

Jordan, E. O. 1926. The interconvertibility of "rough" and "smooth" bacterial types. Jour. Amer. Med. Assoc. 86:177-178.

Kauffmann, F. 1930. Die Technik der Typenbestimmung in der Typhus-Paratyphusgruppe. Centralbl. Bakt. I Abt., Orig. 119:152-160.

Koser, S. A., and Styron, N. C. 1930. The production of smooth from rough forms of Bacterium dysenteriae Sonne. Jour. Infect. Diseases 47:443-452.

Lancefield, R. C., and Todd, E. W. 1928. Antigenic differences between matt hemolytic streptococci and their glossy variants. Jour. Expt. Med. 48: 769-790.

Li, C. P. 1929. Studies on the dissociation of the hog cholera bacillus. I. The isolation and differentiation of dissociants. II. Serological reactions, virulence, and stability of the variant forms. III. Active immunization with R forms. Jour. Expt. Med. 50:245-254, 255-262, and 767-775.

Löhnis, F. 1922. Studies upon the life cycles of the bacteria. Mem. Nat. Acad. Sci. Part I:1-335.

Mackie, T. J. 1920. Variation in agglutinability of bacteria associated with variation of cultural characters. Brit. Jour. Expt. Path. 1:213-217.

MacKenzie, G. M., and Fitzgerald, H. 1933. Studies in microbic dissociation. I. The effects of dissociation upon the antigenic behavior of Salmonella and Shigella cultures. Jour. Immunol. 25:397-417.

Mallmann, W. L. 1932. The dissociation of Salmonella pullorum and related species. Mich. Agr. Expt. Sta. Tech. Bul. 122:3-40.

Massini, R. 1907. Ueber einen in biologischer Beziehung interessanten Kolistamm (Bacterium coli mutabile). Arch. Hyg. 61:250-292.

Müller, R. 1911. Mutationen bei Typhus and Ruhrbakterien (Mutationen als spezifisches Kulturmerkmal). Centralbl. Bakt. I Abt., Orig. 58:97-106.

Nägeli, C. v. 1877. Untersuchungen über die niedere Pilze und ihrer Beziehung zu den Infektionskrankheiten und der Gesundheitspflege. (Cited by Hadley, P. Microbic dissociation. Jour. Infect. Diseases 40:1-312, 1927.)

Nicolle, Ch. 1898. L'agglutination spontanee des cultures, ses rapports avec L'agglutination par les serums. Compt. Rend. Soc. Biol. [Paris] 50:1054-1055.

Peckham, A. W. 1907. The influence of environment upon the biological processes of the various members of the colon group of bacilli. Jour. Expt. Med. 2:549-591.

Penfold, W. J. 1911. Studies in bacterial variation. (With special reference to the chemical functions of the members of the Typhoid-Coli group.) Jour. Hyg. [London] 11:30-67.

Penfold, W. J. 1912. On the specificity of bacterial mutation. (With a résumé of the results of an examination of bacteria found in feces and urine, which undergo mutation when grown on lactose medium.) Jour. Hyg. [London] 12:195-217.

Plastridge, W. N., and Rettger, L. F. 1930. An epidemic disease of domestic fowl caused by a hitherto undescribed organism of the Salmonella pullorum type. Jour. Infect. Diseases 47:334-339.

Plastridge, W. N., and Rettger, L. F. 1932. Variants of Salmonella pullorum. Jour. Infect. Diseases 50:146-161.

Plastridge, W. N., and Rettger, L. F. 1934. Virulence of Salmonella pullorum. Jour. Infect. Diseases 54:23-34.

Preisz, H. 1904. Studien über Morphologie und Biologie des Milzbrandbacillus. Centralbl. Bakt. I Abt., Orig. 35:280-293.

Rettger, L. F. 1900. Septicemia among young chicks. N. Y. Med. Jour. 71:803-805.

Rettger, L. F., and Harvey, S. C. 1908. Fatal septicemia in young chickens, or "White Diarrhea." Jour. Med. Research 18:277-290.

Rettger, L. F., and Sherrick, J. L. 1911. Studies on bacterial variation. Jour. Med. Research 24:265-284.

Rettger, L. F., and Plastridge, W. N. 1932. Pullorum disease of domestic fowl. Monograph. Conn. (Storrs) Agr. Expt. Sta. Bul. 178.

Rettger, L. F., and Gillespie, H. B. 1933. Bacterial variation, with special reference to pleomorphism and filtrability. Jour. Bact. 26:289-317.

Revis, C. 1912. The production of variation in the physiological activity of Bacillus coli by the use of malachite green. Roy. Soc. [London] Proc., Ser. B. 85:192.

Roux, E. 1890. Bactéridie charbonneuse asporogène. Ann. Inst. Pasteur 4:25-34.

Rowland, S. 1914. The influence of cultivation in serum containing media upon the virulence and immunizing properties of the plague bacillus. Jour. Hyg., Plague Supplement 3:403-411.

Savage, W. G. 1901. Pseudo-clumping in cultures of the typhoid bacillus. Jour. Path. and Bact. 7:388-399.

Savage, W. G., and White, P. B. 1925. An investigation of the Salmonella group, with special reference to food poisoning. Special Report Series No. 91, Med. Research Council (London).

Schütze, H. 1921. The permanence of the serological paratyphoid B. types, with observations on the non-specificity of agglutination with "rough" variants. Jour. Hyg. [London] 20:330-341.

Soule, M. H. 1928. Microbic dissociation (B. subtilis). Jour. Infect. Diseases 42:93:148.

Stearn, E. W., and Stearn, A. E. 1933. The effect of the reaction of the medium on the characteristics of bacteria. I. General presentation of the problem, and results obtained with Bacillus coli-communior, Salmonella enteritidis and Pseudomonas pyocyanea. Jour. Bact. 26:9-36.

Steinhardt, E. 1904. Variations in virulence in organisms acted upon by serum, and the occurrence of spontaneous agglutination. Jour. Med. Research 13:409-418.

Twort, F. W. 1907. The fermentation of glucosides by the bacteria of the typhoid-coli group and the acquisition of new fermenting powers by B. dysenteriae and other microorganisms. Roy. Soc. [London] Proc., Ser. B. 79:320-336.

Webster, L. T., and Pritchett, I. W. 1927. Studies on the mode of spread of B. enteritidis mouse typhoid infection. I. Native epidemicity. Jour. Expt. Med. 46:847-853.

Webster, L. T., and Burn, C. 1927. Studies on the mode of spread of B. enteritidis mouse typhoid infection. III. Studies of bacterial cells taken from smooth, mucoid and rough colonies. Jour. Expt. Med. 46:871-886.

White, P. B. 1926. Further studies of the Salmonella group. Special Report Series, No. 103, Med. Research Council (London).

White, P. B. 1928. Further notes on spontaneous agglutination of bacteria. Jour. Path. and Bact. 31:423-433.

White, P. B. 1932. Observations on Salmonella agglutination and related phenomena. Concerning an alcohol-soluble antigen (Substance Q). Jour. Path. and Bact. 35:77-89.

White, P. B. 1933. Observations on Salmonella agglutination and related phenomena. IV. The p-variant and an antigen soluble in acidified 75 per cent alcohol. Jour. Path. and Bact. 36:65-76.

Wilson, G. S. 1928. Discontinuous variation in the virulence of Bact. aertrycke Mutton. Jour. Hyg. [London] 28:295-317.

Publication of this Document Approved by Commission on Administration and Finance
2500-6-'35. No. 4732.

VIRGINIA POLYTECHNIC INSTITUTE
AGRICULTURAL BRANCH LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 320 June, 1935

Pruning Bearing Apple Trees

By J. K. Shaw

Few careful experiments have been made to determine whether current beliefs and practices in regard to pruning bearing apple trees are sound. For the last eight years this Station has carried on experiments directed toward this end. These are reported in this bulletin.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

PRUNING BEARING APPLE TREES

By J. K. Shaw, Research Professor of Pomology

The usual practice in growing apple trees involves pruning of considerable severity. When seedling trees are dug and transferred from the seedling bed to the nursery proper, severe root pruning is required and to restore the balance between root and top, the top is usually cut back rather severely. The process of grafting or budding necessitates further rather drastic pruning. Then follows transplanting to the orchard, with further root and top pruning. The statement that "all pruning is to correct the evils caused by previous pruning" contains much truth.

All who have studied the growth of young trees in the orchard are agreed that pruning is necessary, though there is some disagreement as to the amount and kind of pruning most desirable. There is a general agreement that it should be light and corrective, not severe and repressive. It should be directed to the arrangement and spacing of the main branches and of the principal laterals growing out from them.

The principles and practice of pruning mature bearing trees differ somewhat from those applying to young rapidly growing trees. When trees begin to bear heavily, generally by the time they are ten or fifteen years old, the emphasis has changed to weeding out weak, slow-growing wood. It is this phase of pruning that is to be considered in this bulletin.

Comparatively few experiments have been made to determine the effects of pruning on the quantity and quality of fruit produced. Some of the more important are here briefly summarized.

Alderman and Auchter[1] found that with young trees fruit production was decreased by pruning, while with mature trees, below normal in vigor, crops of Arkansas and York Imperial were increased by pruning.

Bachelor and Goodspeed,[2] working in Utah through a four-year period, found that with young bearing Gano trees pruning reduced the crop, especially when pruning was more severe or done in the summer. With similar Jonathan trees, winter pruning increased the yield except when the trees were pruned also in the summer.

Bedford and Pickering[3] concluded that the more pruning can be reduced the better. Pruning young trees reduced the crops severely; with older trees, the crop reduction was not so much.

Marshall[4] made the most extensive experiments in pruning bearing trees. He found that pruning resulted in larger fruits and consequently a higher proportion of the better grades, but the yields and net returns were smaller except with trees low in vigor. There was no appreciable effect of pruning on disease and insect control. There was no profit from pruning old but fairly vigorous trees; there was a profit from pruning trees very low in vigor. Data from young bearing trees were too limited to warrant conclusions. In general more liberal nitrogen applications gave larger increases in net returns than did pruning. Pruning cannot be regarded as a substitute for thinning as the former removes both good and poor fruits, while in the latter some selection can be made. Profits depend much upon high yields, and pruning, especially if rather severe, decreases yields. However, Marshall does not recommend that bearing trees be left unpruned. Dead and weak wood must be removed, and pruning may facilitate orchard operations such as spraying, thinning, harvesting, and cultivation, and keeps the trees from becoming too high.

---

[1] Alderman, W. H., and E. C. Auchter. Pruning fruit trees. W. Va. Agr. Expt. Sta. Bul. 164. 1917.

[2] Bachelor, L. D., and W. E. Goodspeed. The summer pruning of a young bearing apple orchard. Utah Agr. Expt. Sta. Bul. 140. 1915.

[3] Bedford, Duke of, and S. U. Pickering. Science and Fruit Growing. London. 1919.

[4] Marshall, R. E. Profit and loss in pruning mature apple trees. Mich. Agr. Expt. Sta. Spec. Bul. 169. 1928.

HofMann[5] obtained considerably larger yields from unpruned trees than from heavily pruned trees, and possible small increases from lightly pruned trees as compared with unpruned trees. These experiments were carried on in Virginia with York Imperial and Stayman.

The reasons usually given for pruning bearing apples trees are well known to all who deal with them. Among them are: pruning increases the average size of the fruit; it facilitates spraying and lessens the amount of injury from insects and diseases; it favors color development; it sometimes increases the size of the crop; and it may promote tree vigor. The experiments here reported were planned to help determine whether or to what degree these reasons are sound.

Description of Orchards

Trees from four orchard blocks have been under observation. Two are of comparatively young orchards, one contains middle-aged trees, and the fourth is made up of old trees.

Block A.—This is an orchard in which a pruning experiment with young trees was conducted. This work has been previously reported.[6] Since it was terminated, the trees that had not been pruned (except to remove suckers and water sprouts) have been so continued. Therefore these trees have never been pruned since they were planted as one-year whips in 1916. The other trees, which were pruned in five different ways up to 1925, have all been moderately pruned each year. The varieties included are Baldwin, Northern Spy, Rhode Island Greening, McIntosh and King. There were five trees of each variety unpruned and five similar trees of each variety pruned in each of five different ways up to 1925. In the spring of 1930 the trees of three types of pruning were removed on account of crowding.

Block K.—This orchard is Wealthy, interplanted with several varieties. The Wealthy trees were planted as fillers but have been retained and the other varieties cut out. There were 144 Wealthy trees planted in 16 rows, 40 feet apart with trees in the center of the squares, the other varieties bringing the planting distance down to 20 feet. The orchard was planted in 1915 and the pruning experiment started in 1921. It was cultivated with cover crops up to April 1928 when it was seeded to timothy and Kentucky blue grass and has since been in sod. The vigor of the trees since seeding varies from poor to good. The trees have tended strongly to biennial bearing in recent years and have borne good crops.

These trees were divided into four lots each distributed through the orchard.

---

[5] HofMann, F. W. Tabular biometrical presentation of pruning treatments with apple trees Amer. Soc. Hort. Sci. Proc. 28:613. 1931.

[6] Shaw, J. K. Head formation in apple trees. Mass. Agr. Expt. Sta. Bul. 238. 1927.

One lot was left unpruned; a second was lightly pruned in the early spring; a third was given similar pruning in the spring followed by a light pruning in the summer soon after terminal buds were formed; and a fourth was given moderately severe pruning. The summer pruning was discontinued after a few years and the third group of trees pruned exactly like the second group. The pruning was all of the same type, differing only in amount, and consisted in removing weak and interfering branches, mostly small ones. No heading back was practiced.

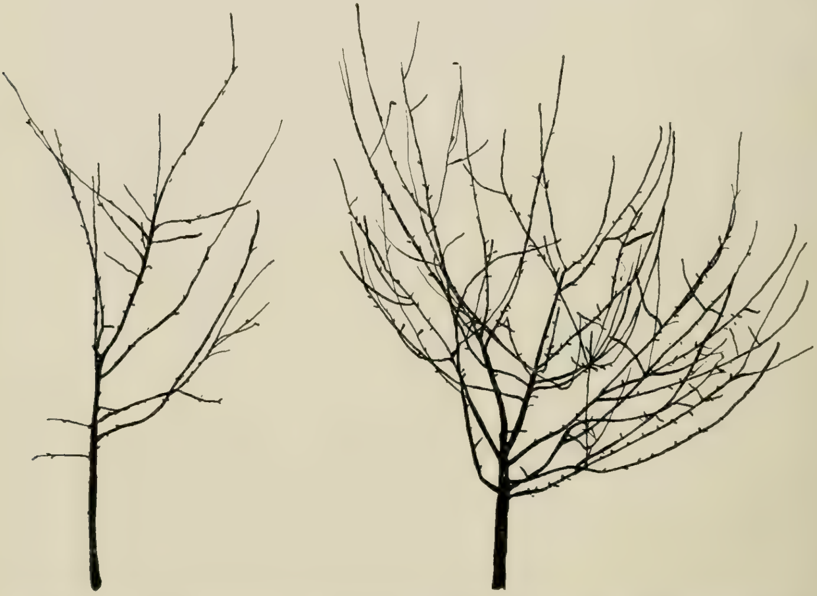


Figure 1. Unpruned King tree at the ages of three and seven years, illustrating the natural balancing of the tree as it grows. The left side of the tree, weaker in the early years, has become the stronger. Moderate corrective pruning would have produced a better balanced tree.

Clark Orchard.[7]—This orchard was planted in 1897. The rows included in the pruning test were Rhode Island Greening, Wealthy, McIntosh, and Ben Davis. They have been under various kinds of soil management and fertilization through the years and are vigorous, productive, and fairly uniform. There is one row of eleven trees of each variety.

The trees had had in recent years a moderate or rather heavy pruning, and in the spring of 1932 about one half of the trees of each variety (omitting a few replants and trees not true to name) were left unpruned and the other trees pruned much as in previous years. This treatment was continued in 1933. Thus there are only two years' results in this orchard but the yields for eight years before are available for comparison.

Block O.—This orchard was planted in 1889 and contained originally sixty trees, 15 trees each of Rhode Island Greening, Roxbury Russet, Baldwin, and Gravenstein. Five trees have died or are in very bad condition. The orchard was originally used for a fertilizer experiment, and a report of this work, in which the orchard was described, has been made.[8] The trees had been moderately pruned each year and had borne well before 1927 when trees were selected for three types of pruning treatment. The trees included in each treatment were selected so that each lot was comparable to the others.

---

[7] Credit for the work in this orchard is due O. C. Roberts of this department, under whose direction the work was carried on.

The pruning treatments were planned as follows: (1) Unpruned trees, no pruning to be done except to remove dead and dying branches if and when they appeared. (2) Lightly pruned trees, to be pruned lightly or moderately, removing weak, slow-growing wood. These trees were pruned about the same as most good orchardists would prune. (3) Heavily pruned trees, to be pruned in the same manner as (2) but more severely. More wood was removed from these trees in the earlier years than in the later years.

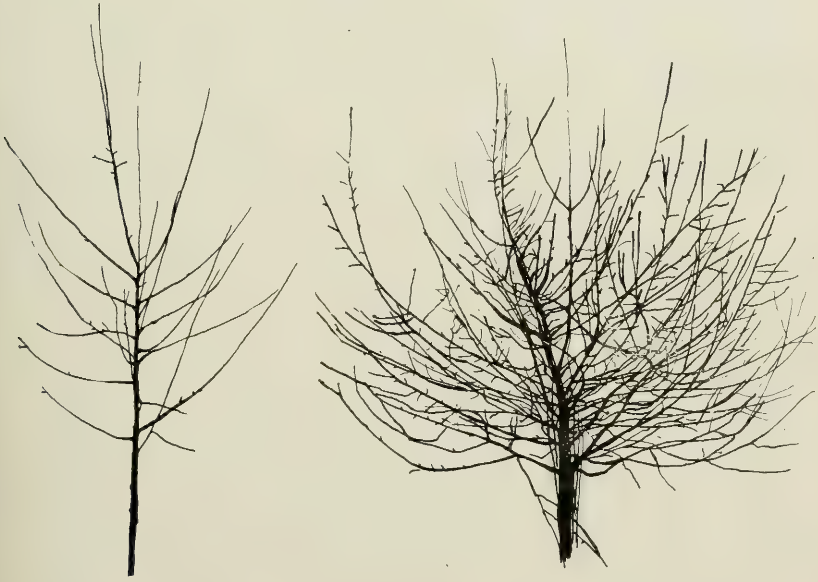


Figure 2. Unpruned McIntosh tree at two and seven years of age. A well-balanced tree has grown. Some of the weaker wood could be removed without lessening the quantity or quality of the crop.

The differential fertilizer treatment was discontinued and the whole orchard given nitrate of soda at the rate of about 300 pounds per acre each year. The orchard has been strip cultivated, about one-third of the surface being kept cultivated during the early part of the season and then a cover crop sown. The growth of the cover crop has been in most years rather poor. The trees are now large for the area but are not seriously crowded. They have all borne very well, the maximum crop of 1930 amounting to nearly 1500 bushels from less than sixty trees.

---

[8] Shaw, J. K. Experiments in Soil Management and Fertilization of Orchards. Mass. Agr. Expt. Sta. Bul. 209. 1922.

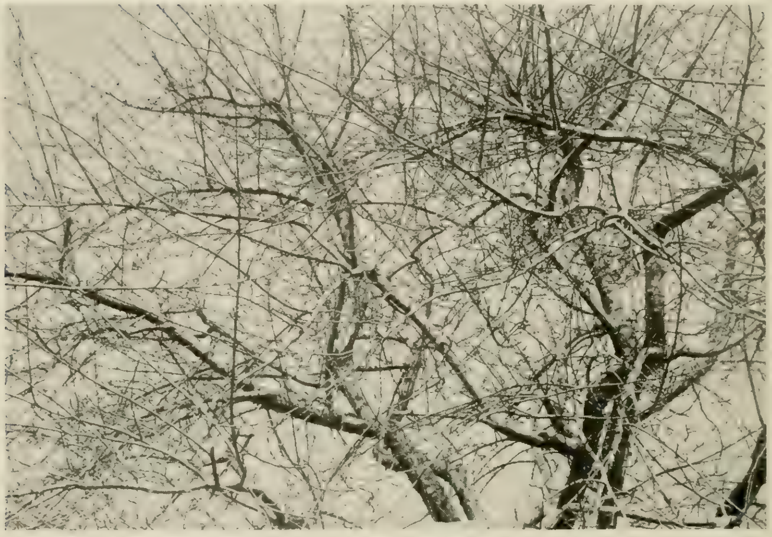


Figure 3. McIntosh tree in Clark Orchard after four years without pruning. Top is excessively thick but production heavy. Quality of the crop is somewhat inferior.

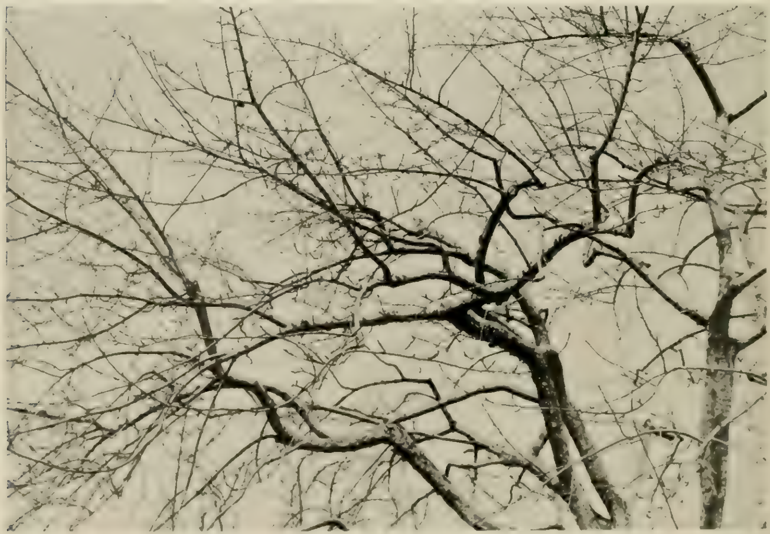


Figure 4. McIntosh tree in Clark Orchard after heavy pruning. Such severe pruning reduces the crop with some improvement in quality. Good pruning lies between that shown in this figure and Figure 3.

Effect of Pruning on Growth

Annual measurements of trunk growth have been made on three of the orchards under consideration. Table 1 gives the average increases in trunk diameter of the trees in Block A from 1924 to 1930.

TABLE 1.—THE EFFECT OF PRUNING ON INCREASE IN TRUNK DIAMETER—BLOCK A, 1924 TO 1930, INCLUSIVE.
(MILLIMETERS)

Previous Treatment	Baldwin	Northern Spy	R. I. Greening	McIntosh	King
Not headed back					
Globular	100	66	80	93	106
Modified leader	103	68	72	70	87
Central leader	97	87	71	81	89
Headed back					
Globular	100	78	91	88	102
Central leader	100	75	63	101	95
Average all pruned	100	75	75	87	96
Unpruned	106	70	81	82	97

The three groups of trees not headed back were removed in 1930, and three groups, including the unpruned trees, remain. Table 2 shows the growth of these trees for the period from 1924 to 1933.

TABLE 2.—THE EFFECT OF PRUNING ON INCREASE IN TRUNK DIAMETER—BLOCK A, 1924 TO 1933, INCLUSIVE.
(MILLIMETERS)

Previous Treatment	Baldwin	Northern Spy	R. I. Greening	McIntosh	King
Headed back					
Globular	151	146	161	144	151
Central leader	153	129	120	142	149
Unpruned	149	114	138	146	151

Study of Tables 1 and 2 fails to reveal any evidence that the uniform moderate pruning given these trees since 1924 has consistently decreased trunk growth.

Annual measurements have been made of the Wealthy trees in Block K. Table 3 shows the increase in trunk diameter made by these trees during the period 1921 to 1932.

This table shows no dwarfing effect of pruning. The lightly pruned trees seem to have made a little more growth, as measured by trunk diameter, than the unpruned trees, also the moderately pruned trees show slightly more growth. This suggests that with these trees pruning has had a slight invigorating influence. It would have been possible to increase growth of these trees by different soil management or more fertilizer and this would have been a more rational practice. This was not done for reasons not concerned with this experiment. If the rows are considered in alphabetical order as they stand in the orchard there will be revealed a progressive decrease in growth from Row D to Row O. These rows run over a rather dry gravelly knoll some twenty feet high which probably accounts for the smaller growth.

TABLE 3.—THE EFFECT OF PRUNING ON TRUNK DIAMETER—BLOCK K, WEALTHY.

(MILLIMETERS)

No Pruning				**Moderate Pruning**			
	1921	1932	Increase		1921	1932	Increase
Row C.....	57	181	124	Row B......	52	177	125
Row G.....	55	174	119	Row F......	61	184	123
Row K.....	62	174	112	Row J.......	58	164	106
Row O.....	53	160	107	Row N......	66	179	113
Average..	56.8	172.3	115.5.	Average...	59.3	176	116.8
Light Pruning				**Light Fruning**			
Row A.....	59	174	115	Row D......	60	193	133
Row E.....	61	188	127	Row H......	58	181	123
Row I.....	59	179	120	Row L......	57	172	115
Row M....	71	181	110	Row P......	58	176	118
Average..	62.5	180.5	118	Average...	58.3	180.5	122.3

The old trees in Block O have been measured by taking the trunk circumference instead of the diameter. The growth of these trees is shown in Table 4.

TABLE 4.—THE EFFECT OF PRUNING ON TRUNK CIRCUMFERENCE—BLOCK O.

(INCHES)

	Unpruned			Lightly Pruned			Heavily Pruned		
	1925	1932	Increase	1925	1932	Increase	1925	1932	Increase
R. I. Greening.......	59.4	64.9	5.5	59.5	64.8	5.3	58.3	63.5	5.2
Roxbury Russet......	49.1	53.3	4.2	49.1	53.4	4.3	48.4	51.9	3.5
Baldwin.............	54.1	59.9	5.8	55.2	60.9	5.7	58.7	66.2	7.5
Gravenstein.........	64.0	71.3	7.3	59.9	67.1	7.2	56.6	61.7	5.1

The heavily pruned Roxbury and Gravenstein seem to have made less and Baldwins more growth than those lightly pruned or unpruned. With the R. I. Greening the differences are slight. It will be noted that, in the case of the Baldwins, the heavily pruned trees were larger than the others in 1926 before the experiment was started, while with the other three varieties the heavily pruned trees were smaller. This suggests that conditions other than pruning have a greater influence on growth. Increases in circumference are more closely correlated with previous size of the trees than with pruning treatment.

It seems very doubtful that pruning as carried out in these experiments with bearing trees has had much dwarfing effect. This is in harmony with earlier experiments by the writer[9] where no dwarfing effect was found if the trees were not headed back.

---

[9] Shaw, J. K. Head formation in apple trees. Mass. Agr. Expt. Sta. Bul. 238. 1927.

Effect of Pruning on Yield

The number of trees in Block A is too small to furnish very dependable data on yield, but they do show some things that are believed to be significant. The total yields of the several varieties for the four years 1927 to 1930 inclusive are shown in Table 5.

TABLE 5.—THE EFFECT OF PRUNING ON TOTAL YIELDS—BLOCK A, 1927 TO 1930, INCLUSIVE.

(POUNDS PER TREE)

Previous Treatment	Baldwin	Northern Spy	R. I. Greening	McIntosh	King	TOTAL
Not headed back						
Globular.....	415	50	508	743	377	2093
Modified leader	835	50	351	839	283	2358
Central leader	411	237	230	875	440	2193
Headed back						
Globular.....	297	44	241	689	323	1594
Central leader	368	199	366	880	219	2032
Average all pruned	465	116	339	805	328	2053
Unpruned......	854	733	376	749	304	3016

The yields are small, for this orchard did not produce a full crop until 1933. The total yields of three of these groups for the years 1924 to 1933, are shown in Table 6.

TABLE 6.—THE EFFECT OF PRUNING ON TOTAL YIELDS—BLOCK A, 1924 TO 1933, INCLUSIVE.*

(POUNDS PER TREE)

Previous Treatment	Baldwin	Northern Spy	R. I. Greening	McIntosh	King	AVERAGE
Headed back						
Globular.....	1972	1002	975	1922	829	1340
Central leader	1546	1183	805	2979	762	1455
Unpruned......	1720	1493	964	2286	1076	1508

*Omitting 1926 and 1932, for which there are no records.

The figures in Table 5 show that the trees which had been headed back in their early years had not recovered and the yields are low. That this handicap was largely overcome in later years is indicated in Table 6. The larger yields of the unpruned Northern Spy trees may have some significance, for other observations have suggested that pruning this variety decreases yields. This is interesting in view of the fact that Spy makes a notably thick top. Perhaps the bearing habit of Northern Spy is involved. There is no conclusive evidence in these tables that pruning has had any great influence on quantity production, provided that heading back the new shoots is not practiced.

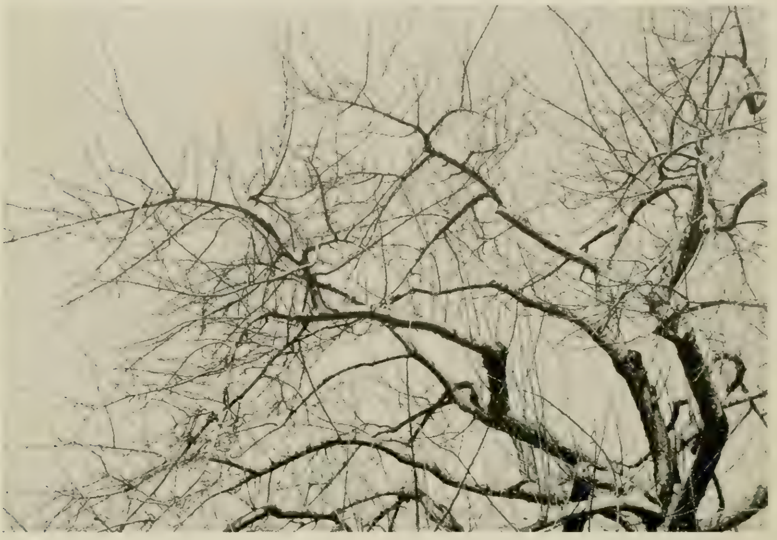


Figure 5. Rhode Island Greening tree forty-five years old, heavily pruned for six years. Note reduced amount of bearing wood and many water sprouts which must be removed.

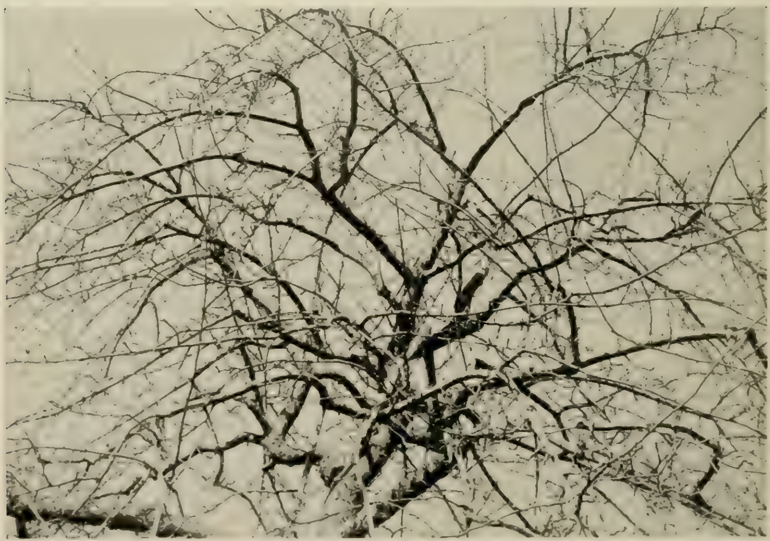


Figure 6. Rhode Island Greening tree forty-five years old, lightly pruned. Top open to light and air and no water sprouts.

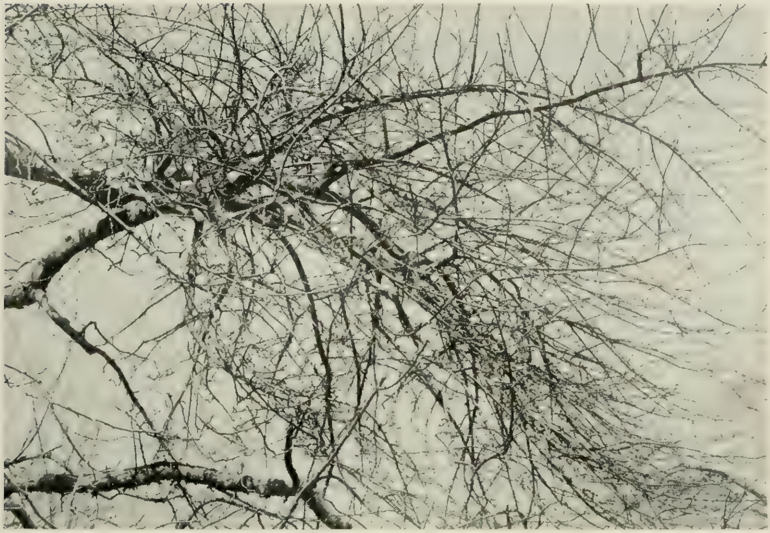


Figure 7. Rhode Island Greening tree forty-five years old, unpruned for six years. The interior of the tree is very thick, and here are borne small apples. The outer part of the tree is still well exposed to light. Many trees thus treated show a great deal of dead and dying wood.

Table 7 shows the yields of Wealthy trees in Block K now 17 years old. In order to show the differences in yield of the four rows pruned alike, each row is given separately and may be compared with the nearest rows receiving different pruning.

TABLE 7.—THE EFFECT OF PRUNING ON AVERAGE ANNUAL YIELDS—BLOCK K, WEALTHY.

(POUNDS PER TREE)

	First Row	Second Row	Third Row	Fourth Row	Average
No pruning......	113	155	130	110	126
Light pruning....	142	162	145	128	144
Light pruning....	171	101	155	131	140
Moderate pruning	111	130	101	121	117

There are considerable differences in yields of the rows pruned alike but the average of the two lots of lightly pruned trees differs by only four pounds and exceeds that of both the unpruned and the moderately pruned trees. This suggests that with these trees of rather low vigor, the increases from light pruning may have some significance and that the heavier pruning may have had an effect in decreasing yields. However, it would have been better, from a practical standpoint, to increase the vigor of the trees by better cultural methods rather than by pruning.

The Clark Orchard includes other varieties and the experiments have continued for a relatively short period. In Table 8 the average annual yields in bushels per tree for a four-year period previous to the differential pruning treatment is compared with the two-year period during which part of the trees were not pruned.

TABLE 8.—THE EFFECT OF PRUNING ON AVERAGE ANNUAL YIELDS—CLARK ORCHARD.

(BUSHELS PER TREE)

	Unpruned Trees				Pruned Trees			
	Number of Trees	Before	After	Gain	Number of Trees	Before	After	Gain or Loss
Ben Davis....	5	15.8	22.7	6.9	6	15.2	20.6	5.4
McIntosh....	4	34.9	47.3	12.4	4	30.3	33.0	2.7
Wealthy......	6	12.8	12.8	0	5	14.2	13.4	–0.8
R. I. Greening	4	20.6	31.4	10.8	4	19.5	24.8	5.3

The number of trees of each variety is small. Allowing these trees to go unpruned for two years has apparently increased the yields of Ben Davis slightly, and of McIntosh and R. I. Greening considerably, and made no material difference with Wealthy. It is interesting to note that the results with Wealthy are similar to those shown with younger trees in Table 7. These Wealthy trees like the others are only moderately vigorous.

In view of the short period and few trees, it cannot be said that there is here any conclusive evidence that pruning has affected yields. More evidence is needed to prove that the increased yield of McIntosh and R. I. Greening is due to leaving the trees unpruned.

The trees in Block O are old and have declined in vigor during the period of this experiment though they produced by far their largest crop in 1930. This heavy crop seems to be largely due to a light yield in 1929 and very favorable weather while the buds and fruit of the 1930 crop were developing.

Table 9 shows the average annual yield of these trees by varieties in pounds of fruit per tree for six years of differential pruning. This is compared with the yields of the same trees for the previous six-year period when they were all pruned alike. The gain or loss in the second period as compared with the first is the significant figure. This is given in percentage of gain over the yield in the earlier period.

TABLE 9.—THE EFFECT OF PRUNING ON AVERAGE ANNUAL YIELDS— BLOCK O.

(POUNDS PER TREE)

	Unpruned			Lightly Pruned			Heavily Pruned		
	Before, 1921-26	After, 1928-33	Gain, percent	Before, 1921 26	After, 1928 33	Gain, percent	Before, 1921 26	After, 1928-33	Gain, percent
R. I. Greening .	895	1102	34	580	900	55	706	875	24
Roxbury Russet	465	813	75	433	619	43	435	515	18
Baldwin....	633	679	7	498	579	16	568	564	–1
Gravenstein...	644	716	11	601	601	0	393	432	10
All Varieties. .			26			27			14

This table shows that heavy pruning has rather consistently reduced yields. All varieties when heavily pruned show less gain in the second or differential pruning period than the unpruned trees and less than the lightly pruned trees except in the case of Gravenstein. Comparisons of the lightly pruned trees with the unpruned trees are conflicting. Rhode Island Greening and Baldwin show greater gains when lightly pruned, while the unpruned Russet and Gravenstein trees gained more than the lightly pruned trees. Too much reliance should not be placed on these differences, but it may be safe to conclude that light pruning has had little effect on the yield of these trees while heavy pruning has reduced yields.

Effect of Pruning on Size, Color, and Blemishes

It is generally believed that it is very difficult or impossible to control insects and diseases in unpruned trees and that red varieties do not color well unless pruned. Data are available from only two of these orchards. Both have been sprayed according to the usual program with power outfits. No attempt has been made to measure the amounts of spray mixture used, but the time required to spray unpruned trees was no greater than that to spray pruned trees. It seems fair to assume that the rate of discharge of liquid was fairly constant and that there could have been no great differences in the amount of spray material used. Not all the data that have been collected are presented here because little would be added to the record. The trend is the same as shown in the tables that are given.

Whenever time permitted, the apples from these orchards were graded according to the Massachusetts or the United States Grading Laws. The rules followed in different years were not exactly the same, but each year the apples were separated into three grades and culls. Of course, the same rules were applied in each year to all apples from trees with different pruning treatment. Some of these results are shown in Tables 10 and 11.

TABLE 10.—EFFECT OF PRUNING ON GRADE AND SIZE OF FRUIT—CLARK ORCHARD, 1933.

Treatment	Percentage of Apples in Each Grade				Percentage of Apples in Each Size, first and second grades only				
	First Grade	Second Grade	Third Grade	Culls	Over 3¼ Inches	3 Inches	2¾ Inches	2½ Inches	Under 2½ Inches
McIntosh									
Sprayed trees									
Pruned......	50.6	39.4	8.8	1.2	0.1	6.6	25.7	51.4	6.2
Not pruned..	36.7	48.8	7.7	6.8	0	5.4	24.1	47.9	8.1
Dusted trees									
Pruned......	32.5	52.9	12.1	2.4	0	11.8	26.0	46.4	1.3
Not pruned..	28.1	58.2	8.4	5.3	0	1.8	13.5	63.6	7.4
Rhode Island Greening									
Sprayed Trees									
Pruned......	52.5	34.1	8.0	5.0	0.1	1.0	8.0	41.9	35.4
Not pruned..	43.9	43.9	8.5	3.7	2.6	7.0	20.6	38.6	21.1
Dusted trees									
Pruned......	54.3	34.1	6.1	5.5	3.3	5.8	13.8	35.5	29.5
Not pruned..	59.4	25.8	8.2	6.6	2.7	9.3	16.7	35.6	20.8

As shown in Table 10, fruit from the sprayed McIntosh trees graded out better from the pruned than from the unpruned trees. There was little difference with the fruit from the dusted trees, but the trend is the same. There was less difference in the case of Rhode Island Greening though there is a similarity. As shown later color was important in determining grade, and this affected the McIntosh but not the Rhode Island Greening.

The results of grading fruit from the old trees, shown in Table 11, are more consistent. Apples from the pruned trees graded out better than those from the unpruned trees. There is no distinct evidence that heavy pruning produced more high-grade and fewer low-grade apples than light pruning, but the comparison between light pruning and no pruning is uniformly in favor of light pruning. It should be noted that this table shows results from the crop of 1932 after the experiment had continued for five years.

TABLE 11.—EFFECT OF PRUNING ON GRADE AND SIZE OF FRUIT—BLOCK O, 1932.

Pruning Treatment	Percentage of Apples In Each Grade				Percentage of Apples in Each Size, first and second grades only				
	First Grade	Second Grade	Third Grade	Culls	Over 3¼ Inches	3 Inches	2¾ Inches	2½ Inches	Under 2½ Inches
Baldwin									
Heavily pruned	15.5	32.9	47.7	3.9	7.5	15.8	15.6	9.0	0.6
Lightly pruned	14.6	30.3	48.6	6.5	4.3	13.0	13.5	11.3	2.7
Unpruned.....	6.5	28.2	54.7	10.6	1.2	4.1	7.1	19.4	2.9
Unpruned (thick trees)..	9.5	27.4	45.3	17.9	1.5	4.0	13.9	15.4	1.0
Rhode Island Greening									
Heavily pruned	49.2	35.6	12.2	4.4	5.1	16.0	34.3	22.9	6.5
Lightly pruned	57.7	25.9	12.0	4.9	6.7	11.3	26.7	27.5	10.0
Unpruned....	46.6	30.4	14.0	9.0	1.9	9.6	30.1	26.1	9.3
Gravenstein									
Heavily pruned	25.9	64.1	5.3	4.6	5.9	32.3	18.3	37.4	6.0
Lightly pruned	35.1	57.3	4.5	3.0	3.5	15.0	39.2	28.3	13.1
Unpruned.....	22.0	63.7	11.7	2.7	0	9.7	35.0	39.7	15.4

It is commonly believed that pruning increases the size of apples. Tables 10 and 11 give some evidence of how the trees in these experiments behaved in this respect. The figures are given in percentages of the total crop, but the third grade and culls were not sized so the totals do not add up to 100. Comparisons can be made of the pruned and unpruned trees for both lots of apples were sized the same.

The trees in the Clark Orchard were included in a comparison of spraying and dusting and the sizing is given for each in Table 10. The figures indicate that with McIntosh the pruned trees gave somewhat larger apples especially on the dusted trees, but there were no consistent differences with the Rhode Island Greenings.

Table 11 shows that pruning increased the size of the apples on these old trees considerably and quite consistently with the three varieties grown. Two unpruned Baldwin trees had especially thick tops and the fruit from these trees was sized separately. There seems to be no indication that the apples from these thick trees were smaller than those on the other unpruned trees.

The figures in these two tables indicate that with trees in full vigor and production, a little increase in size resulted from pruning. With old trees declining in vigor, marked increase in size followed pruning.

Turning now to the reasons why apples fell into the lower grades, Tables 12 and 13 give the percentage of apples placed in lower grades because of poor color, size, scab, and various insect pests. These total more than 100 because of duplicates, some apples showing two or more blemishes any one of which would cause the apple to be placed in a lower grade.

TABLE 12.—EFFECT OF PRUNING ON REASONS FOR LOWER GRADES—CLARK ORCHARD, MCINTOSH, 1931.

(PERCENTAGE OF APPLES)

	Second Grade		Unclassified	
	Pruned	Not Pruned	Pruned	Not Pruned
Mechanical	29.6	19.6	63.4	73.0
Color	51.9	80.2		
Codling Moth	6.4	3.1	13.6	14.4
Scab	20.8	9.8	32.0	12.1
Maggot	1.6	1.4	0	1.5
Curculio	6.7	5.9	5.3	8.3
Red Bug	1.5	0.7	1.1	2.2
Deformity	2.6	3.0	4.8	6.8

TABLE 13.—EFFECT OF PRUNING ON REASONS FOR LOWER GRADES—CLARK ORCHARD, MCINTOSH, 1934.

(PERCENTAGE OF APPLES)

	Second Grade		Unclassified		Culls	
	Pruned	Not Pruned	Pruned	Not Pruned	Pruned	Not Pruned
Sprayed Trees						
Mechanical	31.7	41.0	42.0	39.3	43.6	28.3
Color	30.0	20.8				
Size						57.4
Scab	38.2	48.4	57.0	64.5	59.1	35.3
Codling Moth	3.9	6.5	1.6	7.5	4.5	4.3
Curculio	5.2	12.1	5.2	8.8	15.4	9.4
Red Bug	0.4	1.5	0	0.6	0.9	1.9
Dusted Trees						
Mechanical	33.6	22.9	39.7	46.8	34.7	28.2
Color	23.7	57.8				
Size					25.0	80.9
Scab	23.5	26.5	48.9	38.6	27.3	18.9
Codling Moth	7.5	5.4	6.9	8.9	13.1	4.8
Curculio	21.5	5.4	21.5	14.9	22.7	8.5
Red Bug	2.8	0	1.3	0.7	0	0.5

The figures are conflicting. While the apples from the unpruned trees may perhaps make the poorer showing on the whole, there is no overwhelming tendency in this direction. One is forced to the conclusion that pruning is not always effective in reducing scab and insect injuries on trees that are thoroughly sprayed with modern spraying outfits of sufficient power and capacity.

Discussion

Some of the more striking results of this work do not appear in the tables, The pickers were unanimous in preferring to work on the pruned trees. In Block O consisting of trees about 40 years old, the time required to cut out dead and dying branches in the later years of the experiment was almost as great as that required to prune the trees in the other classes. When trees grow old and begin to decline in vigor, dying wood must be cut out. To leave it would invite decay and a more rapid decline of the trees.

With younger bearing trees in full vigor of growth, pruning has less effect in improving size and quality of fruit than has been commonly believed. Favorable soil conditions, good cultural methods, an adequate fertilizer program, and thinning when trees are heavily loaded are of primary importance in improving size and quality.

Thorough and timely spraying with suitable materials is, of course, of the greatest importance; and the modern high-powered spray outfit may control insects and diseases almost, if not quite, as well on unpruned as on pruned trees.

Cutting out weak and declining wood will not decrease the size of the crop but will eliminate much of the low-grade fruit that scarcely pays for handling. A good time to learn to prune bearing trees is when the crop is on the trees. The type of wood that bears inferior fruit should be noted and removed at pruning time. This will be found to be the small, weak, shaded branches. The sooner they are out of the way, the better. Well-cared-for bearing trees should be gone over annually, if possible, but at least every two or three years, and this type of wood removed. Water sprouts should be removed unless needed to maintain or renew the top. However, if one is forced to economize on labor, it is less injurious to neglect pruning than to cut down on spraying or neglect proper cultural treatment.

No attempt has been made to calculate the financial returns from pruning. These will be different with different growers. Some may be able to sell low-grade fruit profitably; with others it will be of no value. However, in general, profits are made on the higher grades. Taking the figures given, any fruit grower can make his own calculations and then determine for his own conditions the financial aspects of the problem.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
5M-7-'35. No. 5008.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 321 **July, 1935**

Tankage as a Source of Protein For Dairy Cows

By J. G. Archibald

VIRGINIA AGRICULTURAL EXPERIMENT

Tankage, especially the better grades, has a common use as poultry and hog feed, but interest in it as a source of protein for dairy cattle is of very recent development. This bulletin is based on investigations of the value of tankage for milk production.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Trustee Committee on Experiment Station

	Term Expires
BUTTRICK, DAVID H., Arlington, *Chairman*	1939
CHANDLER, JOHN, Sterling Junction	1935
RUSSELL, HOWARD S., Waltham	1936
FROST, HAROLD L., Arlington	1938
MALCOLM, DAVID J., Charlemont	1939
WHITMORE, PHILIP F., Sunderland	1941

Experiment Station Staff, July 1935

HUGH P. BAKER, President of the College

SIEVERS, FRED J., Director
GASKILL, EDWIN F., Assistant to the Director
KENNEY, FRED C., Treasurer
CHURCH, LUCIA G., Secretary

*BOURNE, ARTHUR I., Entomology
*BRADLEY, LEON A., Bacteriology
*CANCE, ALEXANDER E., Economics
*CHENOWETH, WALTER W., Horticultural Manufactures
DORAN, WILLIAM L., Botany
*EISENMENGER, WALTER S., Agronomy
FELLERS, CARL R., Horticultural Manufactures
*FRANDSEN, JULIUS H., Dairy Industry
†*FRANKLIN, HENRY J., Cranberries
*GASKILL, EDWIN F., Station Service
GIBBS, CHARLES S., Veterinary Science
*GRAHAM, JOHN C., Poultry Husbandry
*GUNNESS, CHRISTIAN I., Agricultural Engineering and Meteorology
*HASKINS, HENRI D., Fertilizer Law
HAYS, FRANK A., Poultry Husbandry
HOLLAND, EDWARD B., Chemistry
‡*KOON, RAY M., Horticulture
*LENTZ, JOHN B., Veterinary Science
*LINDSEY, ADRIAN H., Agricultural Economics and Farm Management
LINDSEY, JOSEPH B., Chemistry (Professor Emeritus)
MORSE, FRED W., Chemistry
*OSMUN, A. VINCENT, Botany
*RICE, VICTOR A., Animal Husbandry
*RITCHIE, WALTER S., Chemistry
*SEARS, FRED C., Pomology
SHAW, JACOB K., Pomology
*SMITH, PHILIP H., Feed, Dairy and Seed Laws
*THAYER, CLARK L., Floriculture
VAN METER, RALPH A., Pomology
VAN ROEKEL, HENRY, Veterinary Science
*WOOD, BASIL B., Library

ARCHIBALD, JOHN G., Chemistry
BAILEY, JOHN S., Pomology
||BERGMAN, HERBERT F., Cranberries
BULLIS, KENNETH I., Veterinary Science
DeROSE, H. ROBERT, Fertilizer Law
‡DEMPSEY, PAUL W., Horticulture
*FELTON, F. ETHEL, Editor
FLINT, OLIVER S., Veterinary Science
FRANCE, RALPH L., Bacteriology
FULLER, JAMES E., Bacteriology
‡GUBA, EMIL F., Botany
JEFFERSON, LORIAN P., Agricultural Economics

JONES, CARLTON P., Chemistry
JONES, LINUS H., Botany
||KIGHTLINGER, CLIFFORD V., Tobacco-Disease Investigations
KUZMESKI, JOHN W., Fertilizer Law
McLAUGHLIN, FREDERICK A., Seed Law
MIGHELL, RONALD L., Agricultural Economics and Farm Management
MITCHELL, HELEN S., Home Economics Research
MUELLER, WILLIAM S., Dairy Industry
‡MULLER, RICHARD T., Nursery Culture
ROZMAN, DAVID, Economics
SPELMAN, ALBERT F., Feed Law
‡WHITCOMB, WARREN D., Entomology
‡WHITE, HAROLD E., Floriculture
‡YOUNG, ROBERT E., Vegetable Gardening

ALLEN, HARRY L., Feed, Fertilizer and Dairy Laws
BALL, ALYN S., Botany
BENNETT, EMMETT, Chemistry
CLAGUE, JOHN A., Horticultural Manufactures
CLARKE, MIRIAM K., Veterinary Science
DONLEY, J. ELIZABETH, Agricultural Economics and Farm Management
‡DONNELLY, EDWARD B., Floriculture
‡GILGUT, CONSTANTINE J., Nursery Culture
HOEFLE, OLIVE M., Seed Law
HOWARD, JAMES T., Feed, Fertilizer and Dairy Laws
HUGHES, MARY C., Pomology
MERRIAM, OREANA A., Home Economics Research
MINER, GLADYS I., Botany
O'DONNELL, MARGARET H., Administration
PARKINSON, LEONARD R., Station Service
ROBERTSON, DORIS W., Agricultural Economics and Farm Management
SANBORN, RUBY, Poultry Husbandry
SHERBURNE, RUTH E., Economics
SNELL, MOSES E., Agronomy
||TRURAN, WALTON E., Cranberries
‡WILSON, HAROLD A., Vegetable Gardening
ZIMNOSKI, FELICIA, Veterinary Science

---

*In charge　　†At East Wareham　　‡At Waltham　　||With U. S. D. A.

TANKAGE AS A SOURCE OF PROTEIN FOR DAIRY COWS

By J. G. Archibald, Assistant Research Professor of Animal Husbandry[1]

INTRODUCTION

Tankage, a common article in the feed and fertilizer market, is a by-product of the meat packing industry, and consists of a mixture of meat scraps, trimmings, and bones, the residue from the preparation of the standard market cuts of meat. It is cooked at high temperatures to sterilize it and to render out most of the fat, and is then dried and ground. The final product is a fine, quite dry meal varying in color from light to dark brown and with a characteristic though not objectionable odor. It is composed almost entirely of protein, calcium (lime), and phosphorus. The source of the last two mentioned is bone, and since the proportions of meat and bone vary, there are several grades of tankage with varying percentages of protein, lime and phosphorus. Tankage is generally sold on the basis of its protein content and the grades vary from 45 percent protein or less, which is usually known as "meat and bone", to 60 percent protein, which is sometimes referred to as "meat meal".

The better grades of tankage have been fed to hogs and poultry for years and to beef cattle to some extent more recently. It is only very recently, however, that it has been thought of as a possible source of protein for dairy cows. At present there is a relative scarcity of protein supplements of plant origin due largely to the drouth of 1934, while at the same time tankage is plentiful and its price per unit of protein is rather attractive. Furthermore, certain investigations have demonstrated an apparent superiority of animal proteins over plant proteins for nutritive purposes.

In view of these facts it was decided to conduct at this station an investigation of the value of tankage for milk production. This was done during the winter of 1934-35, the feeding trial lasting somewhat over five months, from November 19 to April 27.

METHOD OF CONDUCTING THE INVESTIGATION

Twenty-four cows were chosen from the State College herd and divided into two groups of twelve each, as similar as possible with respect to breed, age, live weight, stage of lactation, amount of milk being produced and fat test of the milk. Table 1 shows that the groups were quite similar in all respects.

The tankage used in the experiment was a high-grade, dry-rendered product. It was compared with a mixture of soybean meal and cottonseed meal. The groups of cows were fed by the double reversal method, one group receiving the tankage ration for forty days while the other received the soybean–cottonseed ration. At the end of that time the rations were reversed, the group which had been receiving tankage being changed to the soybean–cottonseed ration and

---

[1] The author desires to make the following acknowledgements: To Wilson & Co., Chicago, who supplied the tankage used in the feeding trial; to C. H. Parsons, farm superintendent at Massachusetts State College, for intelligent and effective cooperation throughout the course of the experiment; and to Thomas Muir, herdsman, who had immediate charge of the animals, and whose attention to detail and interest in the work contributed to its success.

vice versa. The rations were reversed three times so that each group received each ration for two different periods of forty days each. Results have been reckoned from the last thirty days of each period, the first ten days being considered preliminary, to allow the cows to become accustomed to the change in feed and to offset any lag in the effect of the previous ration on milk production. Table 2 shows the schedule of the experiment.

The composition of the grain mixtures is given in Table 3.

TABLE 1.—STATUS OF THE TWO GROUPS OF COWS AT THE BEGINNING OF THE EXPERIMENT.

	Group A	Group B
Breed:		
Shorthorns	3	2
Ayrshires	1	2
Holsteins	4	4
Guernseys	3	2
Jerseys	1	2
Average age	5 years 4 months	5 years 6 months
Average weight	1148 pounds	1147 pounds
Average stage in lactation	81 days	77 days
Average daily milk yield	32.8 pounds	32.8 pounds
Average butter fat	4.18 per cent	4.35 per cent

TABLE 2.—SCHEDULE OF FEEDING PERIODS.

Period	Ration fed to Group A	Ration fed to Group B
Nov. 19—Dec. 28, inclusive	Soybean–cottonseed	Tankage
Dec. 29—Feb. 6, inclusive	Tankage	Soybean–cottonseed
Feb. 7—Mar. 18, inclusive	Soybean–cottonseed	Tankage
Mar. 19—Apr. 27, inclusive	Tankage	Soybean–cottonseed

TABLE 3.—FORMULAS OF GRAIN MIXTURES.

Ingredients	Soybean–cottonseed Meal Mixture (Pounds)	Tankage Mixture (Pounds)
Wheat bran	400	400
Ground oats	500	500
Hominy feed	640	640
Soybean meal (41% protein)	200	...
Cottonseed meal (41% protein)	200	...
Corn starch	...	100
Tankage	...	340
Steamed bone meal	40	...
Salt	20	20
TOTAL	2000	2000

TABLE 4.—AMOUNTS OF FEED EATEN.

Feed	Soybean–Cottonseed Ration		Tankage Ration	
	Total for the Group (Pounds)	Daily Average per Cow (Pounds)	Total for the Group (Pounds)	Daily Average per Cow (Pounds)
Hay and rowen[1]	15,813	11.30	15,807	11.29
Corn silage	46,320	33.09	46,335	33.10
Mangels[2]				

The amounts of soybean meal and cottonseed meal in the grain mixture were chosen as typical of the percentages of these ingredients occurring in commercial dairy rations. With two exceptions the mixtures were similar. Due to its somewhat higher protein content, 340 pounds of tankage furnished an amount of digestible protein equivalent to that contained in 200 pounds each of the two oil meals. Because of the presence of bone in the tankage, bone meal was not included in that mixture. The difference (60 + 40 = 100 pounds) was made up by including in the tankage mixture 100 pounds of corn starch per ton. Corn starch was chosen for this purpose because it did not add to the mixture any further protein or minerals.

Except for the variation in the grain mixtures the rations were kept as nearly identical as possible. The other feeds were hay, rowen, corn silage, mangels, and dried beet pulp. Table 4 shows that the average daily intake of feed by the two groups was practically identical. The only feed wasted was small amounts of hay and rowen, which were about the same in each group and constituted about 6.0 percent of the combined amount of hay and rowen fed and about 2.3 percent of the total dry matter of the entire ration.

TABLE 6.—AVERAGE DAILY INTAKE OF NUTRIENTS PER COW.[1]

	Soybean–cottonseed Ration	Tankage Ration
Total dry matter	28.04 pounds	28.08 pounds
Total ash	1.69 pounds	1.90 pounds
Digestible protein	2.38 pounds	2.46 pounds
Total digestible nutrients	19.15 pounds	19.24 pounds
Net energy	18.51 therms	18.60 therms
Nutritive ratio	1:7.0	1:6.8

[1]This includes all material fed—not merely the grain mixtures.

The composition of the feeds as set forth in Table 5 has been used together with average digestion coefficients to obtain the intake of nutrients as recorded in Table 6. It will be noted that the intake was slightly higher on the tankage ration than on the soybean–cottonseed ration. This was unintentional, and was due chiefly to the fact that the grain mixture which contained the tankage proved to be somewhat higher than the other mixture in ash, protein, and fat. Preliminary calculation when the formulas of the mixtures were decided on had indicated the composition of the two to be in theory nearly identical. The tankage analyzed somewhat above its guarantee for protein, which accounts in part for the discrepancy.

RESULTS OF THE FEEDING TRIAL

Palatabilty of the Tankage

No difficulty was experienced in getting the cows to eat the grain mixture which contained tankage. One cow refused her grain on the first day of the trial but not thereafter. The herdsman states that in general the cows did not clean up the tankage mixture as quickly as they did the soybean–cottonseed; but, as already stated, they did not refuse it. The amount of tankage in the grain was 17 percent.

Changes in Live Weight

The cows were weighed when the trial was started and thereafter at the end of each forty-day feeding period, just previous to the change of rations.

Table 7 shows that there was a slightly superior gain in weight on the tankage ration, but calculation of the probable error of the average values given shows that the difference in favor of the tankage is not significant.

General Appearance of the Cows

All animals in the experiment were graded for condition twice during the season. The average grade was "good" tending toward "excellent" as the experiment and the barn feeding season drew to an end. No differences were apparent to the eye in the condition of the animals on the two rations.

Milk Production

A summary of milk production on the two rations appears in Table 8. The figures given have been corrected to a uniform fat basis of 4 percent according to the usual formula ($.4M+15F$), in which M equals actual milk production and F equals calculated fat production based on the fat test of the milk and the actual milk production. Due to a close agreement between the butterfat tests for the two groups of cows, the corrected values in Table 8 do not differ greatly from the actual milk production.

Table 8 shows a slight difference in milk production in favor of the tankage ration, but calculation of probable error shows that this difference is not significant.

Composition of the Milk

Composite milk samples were taken from each group of cows about midway of each feeding period. The sampling period was two days in length and samples from individual cows in a group were pooled to make a group sample. Table 9 shows that there was no significant difference between the rations in this respect.

TABLE 7.—SUMMARY OF AVERAGE GAINS IN LIVE WEIGHT.

	On Soybean–cottonseed Ration (Pounds)	On Tankage Ration (Pounds)
First 40-day feeding period	18	15
Second 40-day feeding period	17	26
Third 40-day feeding period	42	45
Fourth 40-day feeding period	–7	–5
Net total	70*	81*

*These values represent average gains by individual cows.

TABLE 8.—MILK PRODUCTION (CORRECTED TO 4 PERCENT FAT).

	On Soybean–cottonseed Ration (Pounds)	On Tankage Ration (Pounds)
First 30-day period	11,273.0	11,213.9
Second 30-day period	10,402.6	10,745.6
Third 30-day period	9,052.8	9,670.8
Fourth 30-day period	8,614.3	8,396.7
Total production	39,342.7	40,027.0
Average daily production per cow[1]	28.1	28.6

[1] Obtained by dividing the total by 1400, the number of cow days on each ration. If all individuals in each group had milked throughout the duration of the experiment, the number of cow days would have been 1440. One cow in each group dried off sooner than anticipated, and both were removed on the same day—forty days previous to the end of the experiment.

TABLE 9.—COMPOSITION OF THE MILK (PERCENTAGES).

	On Soybean–cottonseed Ration	On Tankage Ration
Total solids	12.76	12.77
Fat	3.96	3.99
Ash	.731	.728

Flavor of the Milk

The composite samples taken for analysis were also scored for flavor, preservative having been purposely omitted with this in mind. The samples were kept sweet by refrigeration and scored (except in one instance) on the same day on which the final aliquots were taken.[1]

On the samples taken in December and April the decision was 3 to 1 that the milk from the cows receiving the soybean–cottonseed ration had slightly the better flavor. On the samples taken in January and March the decision was unanimous that the milk from the cows receiving the tankage ration was slightly the better as regards flavor.

---

[1] Acknowledgement is made to M. J. Mack and H. G. Lindquist of the Department of Dairy Industry of Massachusetts State College, who with two graduate assistants made the tests for milk flavor; also to W. S. Mueller of the same department, who tested the whipping quality of the cream.

The decision was also evenly divided as regards the groups of cows, which rules out individuality of the animals as a factor in influencing the flavor. It may be concluded that the tankage did not affect the flavor of the milk in any way.

Whipping Quality of the Cream

The entire production of each group of cows for one milking was kept separate on two occasions, the cream was separated, and a representative portion of each lot was submitted to the whipping test. To quote the statement of the member of the Department of Dairy Industry who made the test,—"the cream obtained from samples A and B was found to be equal in whipping rate, degree of stiffness and overrun. No objectionable flavor was detected."

SUMMARY AND CONCLUSIONS

High-grade, dry-rendered tankage has been compared as regards its suitability for dairy cows with a mixture of soybean meal and cottonseed meal. The comparison has been made by means of the double reversal method using twenty-four cows in the State College herd, divided into two groups of twelve each. The feeding period extended over 160 days, each group of cows being on each ration at two different times for periods 40 days in length. Tankage made up 17 per cent of the experimental grain ration, and supplied digestible protein equal in amount to that in the 10 percent each of soybean meal and cottonseed meal which the control ration contained.

No difficulty was experienced in getting the cows to eat the grain ration which contained the tankage.

There was no significant difference in the effect of the tankage ration as compared with the soybean–cottonseed ration in any of the following respects: Gain in weight, general appearance of the cows, milk production, composition and flavor of the milk, and whipping quality of the cream.

Insofar as these results are concerned, it seems that high-grade tankage can be safely added to the list of protein feeds for dairy cows, provided the usual precautions for feeding protein concentrates are observed. In addition to its protein, tankage carries a considerable amount of bone, which can take the place of the bone meal so often added as a mineral supplement to mixed feeds.

Publication of this Document Approved by Commission on Administration and Finance
4M-8-'35. No. 5389.

b
2

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 322 JULY 1935

The Effect of Fertilizers on the Longevity of Mowings

By A. B. Beaumont, R. W. Donaldson, and M. E. Snell

VIRGINIA AGRICULTURAL EXPERIMENT STA.

Hay occupies about three fourths of the crop land of Massachusetts and ranks very high in economic importance. This naturally results in an interest in increasing the productiveness and prolonging the life of meadows. This bulletin gives results from experiments in which fertilizers were used as top-dressing on mowings for the purpose of maintaining or improving the yield and quality of hay.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE EFFECT OF FERTILIZERS ON THE LONGEVITY OF MOWINGS

By A. B. Beaumont, Professor of Agronomy, R. W. Donaldson, Extension Agronomist, and M. E. Snell, Technical Assistant in Agronomy

Introduction

Occupying about 70 percent of the harvested crop land, hay is easily the most important field crop in Massachusetts from the standpoint of acreage. In economic value, it is exceeded only by the vegetable crop. With the decline in the horse population in recent years, the demand for market hay has decreased until practically all hay produced in Massachusetts is now fed on the farm where grown. Thus it is marketed through the important dairy industry which produces about 35 percent of the income of Massachusetts farmers.

According to the Federal Census of 1930, the yield of all hay in Massachusetts was 1.3 tons per acre.[1] In view of the importance of the hay crop and the demonstrated possibilities of increased production, this figure is not as high as it should be. Likewise, the quality is poor and can be improved along with the yield; for within limits, the quality of hay improves as the yield per acre increases. More forage of good quality is a primary requirement of dairymen of the Northeastern States. The improvement of the hay crop offers attractive possibilities of reducing costs of producing dairy products in Massachusetts.

Hay is grown in a long rotation on the average Massachusetts farm. Common practices are to seed down after one or two years of corn, small grain, potatoes, or a combination of these, or to plow and reseed an old mowing without growing a tilled crop. It is not uncommon for a mowing to be continued five or more years without reseeding. Decline in quantity and quality of hay finally forces the farmer to plow, but only with the object of getting the land back in hay as soon as possible.

There are several good reasons why it is desirable to prolong the life of mowings in Massachusetts. In the first place, much of the land used for hay in this State is so stony as to make plowing difficult. Secondly, since under ordinary conditions it is more economical for the Massachusetts dairyman to purchase his grain than to produce it, a relatively large acreage must be kept in forage crops. Finally, farm labor is relatively more expensive in Massachusetts than in less industrialized regions, and any method of farming which reduces labor expenditures is desirable. The two experiments reported in this bulletin were designed to show what could be done with fertilizers applied as top-dressing to prolong the life of a mowing.

Experiments with Fertilizers Containing Nitrogen, Phosphorus, and Potassium

This experiment was conducted on one of the deeper and better phases of Merrimac fine sandy loams, a soil rather typical of some of the best hay land in Massachusetts. Although well drained, the soil is retentive of moisture and the field so situated with reference to a drumloid hill that there is some seepage of water from higher elevations. The soil withstands quite well the effects of moderate drouth. The reaction of the soil at the beginning of Part A of the experiment in 1928 was about pH 6.5, and it was maintained near that point throughout. The field had been used for corn, then seeded down in the standing corn with a mixture of timothy and redtop grasses and red and alsike clovers. At the beginning of the experiment the mowing was three or four years old and the vegetation consisted of about 50 percent timothy, 30 percent redtop, 5 percent clovers, 5 percent Kentucky blue grass, 5 percent sweet vernal, and 5 percent weeds.

---

[1] Preliminary census reports for 1935 indicate an average yield of hay less than 1.3 tons per acre.

After Part A had been in progress four years, a parallel experiment (Part B) was started on another part of the same field. The soil conditions were very similar and the mowing of the same age, but the character of the flora was somewhat poorer than on Part A when that experiment was begun.

The quantities of nitrogen, phosphoric acid, and potash and their ratios are given in Table 1. There were three groups of fertilizer treatments, in each of which one nutrient was varied while the other two were held constant. In Part B, the variable nutrient was omitted in one treatment of each series. Nitrogen was supplied by a mixture of equal parts of sodium nitrate and ammonium sulfate; phosphoric acid, by superphosphate; and potash, by muriate of potash. All fertilizers were applied in the early spring about the time that grass begins to grow rapidly, except that in the case of the highest amount of nitrogen, 50 pounds were applied in the spring and the remainder immediately after the first cutting.

TABLE 1.—POUNDS OF NUTRIENTS USED PER ACRE AND THEIR RATIOS.

	Experiment 1A				Experiment 1B			
	N	P_2O_5	K_2O	Ratio	N	P_2O_5	K_2O	Ratio
Nitrogen Series:								
High	75	37.5	37.5	6 : 3 : 3	100	37.5	37.5	8 : 3 : 3
Medium	50	37.5	37.5	4 : 3 : 3	50	37.5	37.5	4 : 3 : 3
Low or none	25	37.5	37.5	2 : 3 : 3	0	37.5	37.5	0 : 3 : 3
Phosphoric Acid Series:								
High	50	100.0	50	4 : 8 : 4	50	133.4	50	4 : 10.67 : 4
Medium	50	66.7	50	4 : 5.33 : 4	50	66.7	50	4 : 5.33 : 4
Low or none	50	33.3	50	4 : 2.67 : 4	50	0	50	4 : 0 : 4
Potash Series:								
High	50	50	100.0	4 : 4 : 8	50	50	133.4	4 : 4 : 10.67
Medium	50	50	66.7	4 : 4 : 5.33	50	50	66.7	4 : 4 : 5.33
Low or none	50	50	33.3	4 : 4 : 2.67	50	50	0	4 : 4 : 0

The plots were 6 by 11 meters, including a border of 1 meter which was cut out and discarded at time of harvest. This made the harvested portion 5 by 10 meters (approximately 2 square rods).[2] Plots were systematically replicated 5 times. Two crops of hay were taken from the field every year except in 1929 when a drouth of unusual severity produced such small second growth as to make cutting inadvisable. The experiment was continued five years, when the quality of the herbage on all but the best plots became so poor that it was decided to plow the field and redirect the experiment.

In Tables 2 and 3 the results of the experiment for the entire period are summarized.

---

[2] As an experiment in the practical application of the metric system of weights and measures to agronomic field experiments, this field was laid out by this system, field weights were taken in it, and of course the laboratory work was carried out with it. The system was found practicable and in some respects easier to use than the English system.

TABLE 2.—MEAN YIELD* AND RANK OF HAY PRODUCED IN EXPERIMENT 1A.

	1928		1929**		1930		1931		1932		Mean	
	Lbs.	Rank	Lbs.	Rank	Lbs.	Rank	Lbs.	Rank	Lbs.	Rank	Lbs.	Rank
Nitrogen Series:												
High	7346	1	4680	2	5010	1	5120	2	3700	1	5171	1
Medium	6501	8	4228	8	3668	8	4505	7	3765	8	4533	8
Low	6181	9	4037	9	3280	9	3514	9	2915	9	3985	9
Phosphoric Acid Series:												
High	6807	5	4329	6	4102	6	4927	3	3891	5	4811	5
Medium	6910	4	4356	5	3932	7	4552	6	3703	6	4691	6
Low	6919	3	4400	4	4188	5	4704	5	3943	4	4831	4
Potash Series:												
High	6798	6	4709	1	4628	2	5328	1	4347	2	5162	2
Medium	6947	2	4589	3	4207	3	4732	4	8816	3	4858	3
Low	6655	7	4238	7	4201	4	4220	8	3540	7	4571	7

*Pounds of dry matter per acre, containing about 4 percent moisture.
**Only one cutting in 1929.

TABLE 3.—MEAN YIELD* AND RANK OF HAY PRODUCED IN EXPERIMENT 1B.

	1932**		1933		1934		Mean	
	Lbs.	Rank	Lbs.	Rank	Lbs.	Rank	Lbs.	Rank
Nitrogen Series:								
High	4576	2	4994	1	4965	1	4845	1
Medium	4270	5	3733	7	3146	7	3716	7
None	2604	9	2952	9	2196	9	2584	9
Phosphoric Acid Series:								
High	4522	4	4116	4	3464	3	4034	4
Medium	4222	6	3887	6	3228	5	3779	6
None	4221	7	3992	5	3188	6	3800	5
Potash Series:								
High	4705	1	4424	2	3738	2	4289	2
Medium	4565	3	4300	3	3431	4	4099	3
None	3841	8	3246	8	2621	8	3233	8

*Pounds of dry matter per acre, containing about 4 percent moisture.
**Second cutting very small on account of dry weather.

Interpretation of the Results of Experiment 1.—By comparing Tables 2 and 3 it will be seen that the results of the two parts of the experiment run almost parallel in the relative effects of the nutrients. Greater differences in yield were obtained from the larger increments of nutrients in part B as was expected. Nitrogen was the most effective nutrient in producing differences in yield, closely followed by potash. Increments of phosphoric acid were of no value in increasing yield of hay in this experiment.

The best comparisons of these results are in the separate series, for it is only in one series that any two nutrients are held constant with the third variable. One series cannot fairly be compared with another, because of variations in pounds of nutrients applied. Thus, the phosphoric acid series ranks higher as a group than the *medium* treatment of the nitrogen series carrying the same amount of nitrogen, probably because of the higher amount of potash in the phosphoric acid series. By the same token the ranking of the phosphoric acid series between the *medium* and *low* (or *none*) of the potash series can be explained.

These results point distinctly to response to nitrogen and potash. The uniformity and consistency of the results, the length of the experimental period, and the methods employed give confidence in the correctness of this conclusion. In the two experiments there was virtually no response to phosphoric acid. Such small positive or negative effects as were obtained most likely come within experimental error or chance variation. In view of the large amounts of phosphoric acid applied in certain treatments, particularly in the *high* treatment of the phosphoric acid series of Part B, it appears that phosphorus was not a limiting factor.

Analyses of the crop from these experiments show a weighted average of 0.54 percent of phosphoric acid in the dry matter, or 0.47 percent on the basis of cured hay with 14 percent moisture. This is about 30 percent higher than the figures given by Henry and Morrison[3] for phosphoric acid in mixed grass hay, main crop and rowen. Readily available phosphoric acid in the untreated soil of these experiments was 318 pounds per acre[4] (2,000,000 pounds of soil) according to the Truog method,[5] and that soluble in N/5 sulfuric acid was much higher. Using the figure of 0.47 percent for the phosphoric acid content of cured hay grown on this soil, a 2-ton crop of cured hay would remove only 18.8 pounds of phosphoric acid per acre per year. It would appear, then, that there was during the course of the experiment an ample supply of available phosphoric acid for the hay crop, and that the potential supply is good.

The question arises as to whether the content of available and potentially available forms of phosphoric acid is high in this soil. The field on which this experiment was conducted had been farmed for many years, and during the fifty-odd years the Experiment Station has had charge of it, more or less phosphatic fertilizer has been applied. In respect to previous fertilizer treatment it was probably in slightly more favorable condition than the average hay land of Massachusetts. No soil without previous fertilization was obtainable in this experiment for determination of *available* phosphoric acid. Therefore, in an attempt to get some idea of the content of this nutrient in unfertilized soil, a sample was drawn from a slightly different soil type in a nearby wood, and available phosphoric acid determined by the Truog method. This was found to be 218 pounds per acre (2,000,000 pounds of soil); a figure not as high as that for the untreated soil of the experiment, but still fairly high. There is no positive assurance that the soil in the wood had not been fertilized at some time in the past; nevertheless the evidence points strongly to the conclusion that the native supply of phosphorus in the soil on which the experiment was conducted was not very low.

Botanical and Chemical Composition of the Hay.—The effect of the fertilizer treatments on the character of the flora grown in these experiments was determined by botanical analysis of samples taken from Experiment 1A in 1931, and by estimates of the composition of the growth on the plots of Experiment 1B in 1933. The results show a slightly superior type of vegetation, particularly with respect to clovers, on the plots which received high potash. On those which received high nitrogen there was a slightly higher percentage of the better grasses. However, the differences were not great in any case. From these experiments it would seem to be impracticable to make any considerable improvement in the quality of the vegetation of an old mowing by the use of fertilizer alone. Deterioration in quality can be deferred by fertilizers, but it appears best to plow and reseed at intervals of 6 to 8 years at most.

The effect of fertilizer treatments on the chemical composition of the hay crop is shown by the analytical data on samples drawn from Experiment 1B and presented in Table 4. The results show only a slight effect of increments of nitrogen on the percentage of this element in the plant. The principal effect of the nitrogen was to alter the size of the mature plant without materially changing its composition, a result in line with the general conclusion stated by Russell.[6] There was no pronounced or consistent effect of the different quantities of phosphoric acid on the percentage of this nutrient in the plant, but, as already pointed out, it runs higher in all treatments in these experiments than the average reported by Henry and Morrison.

---

[3] Henry, W. A., and Morrison, F. B. Feeds and feeding. The Henry-Morrison Co., Ithaca, N. Y. 1925.

[4] Determination made by John N. Everson.

[5] Truog, Emil. The determination of readily available phosphorus in soils. Jour. Amer. Soc. Agron. 23:788-799. 1931.

TABLE 4.—PERCENTAGE OF NUTRIENTS IN THE DRY MATTER OF HAY FROM EXPERIMENT 1B IN 1933*.

	First Cutting			Second Cutting		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Nitrogen Series:						
High	1.60	0.37	1.12	2.24	0.63	1.04
Medium	1.41	0.54	1.32	2.26	0.82	1.42
None	1.39	0.49	1.28	2.26	0.60	1.45
Phosphoric Acid Series:						
High	1.44	0.43	1.55	2.11	0.77	1.35
Medium	1.39	0.43	1.40	2.30	0.68	1.38
None	1.33	0.35	1.48	2.14	0.53	1.51
Potash Series:						
High	1.49	0.56	2.36	2.18	0.70	1.66
Medium	1.39	0.51	1.62	2.20	0.80	1.53
None	1.54	0.56	0.80	2.33	0.84	1.10

*Dry matter and nitrogen determinations reported in this bulletin were made in the Feed Control Laboratory under the direction of Philip H. Smith. Phosphoric acid and potash were determined in the Fertilizer Control Laboratory under the direction of H. D. Haskins.

The percentage of potash was considerably increased by fertilizer treatment. According to figures given by Henry and Morrison[7] for the average potash content of mixed grasses, it might be concluded that there was a luxury consumption of potash in all but the check plot. However, the soil conditions under which the samples reported by Henry and Morrison were grown are not known to the present writer and probably not to anyone. It is possible that they were grown on potash-deficient soils. In view of the increases obtained by increments of potash in this experiment, it seems that this nutrient was a limiting factor. It is quite possible, however, that the highest quantity of potash applied (133.4 pounds) was more than was necessary for the quantity of nitrogen (50 pounds), or even of phosphoric acid, with which it was used.

Experiment 1A was redirected in 1933. The field was plowed and reseeded. Superphosphate was applied to the plowed ground and harrowed in, in amounts equal to a 5-year application at the rates previously used. The experiment will be continued under the previous plan of fertilization. Results to date have been very similar to those of the previous period; namely, showing a response to nitrogen and potash.

Conclusions.—On soils of this type in Massachusetts, the quality and yield of the forage can be improved and the life of the mowing prolonged by the use of fertilizers. However, the quality of hay will deteriorate to such a point in 6 to 8 years that reseeding is advisable, even if fertilizers are used at fairly high rates. On this and closely related soil types, which have been fertilized for a number of years with phosphatic fertilizers, the best returns may be expected from fertilizers high in nitrogen and potash, provided the reaction of the soil is not strongly acid. A fertilizer having a ratio of N, P_2O_5, and K_2O of about 3: 1: 2 is recommended.

---

[6] Russell, E. J. Soil conditions and plant growth. Longmans, Green & Co., London. 1932.

[7] Henry, W. A., and Morrison, F. B. *Op. cit.*

An Experiment in Which Only Nitrogen Fertilizers Were Used

In view of the marked response to nitrogen obtained in the preceding experiment, it was decided in 1932 to start a second experiment for the purpose of studying the effect of nitrogen fertilizer alone on an old mowing. The history of the field chosen for the experiment and the soil conditions were similar to those of the previous experiment, except that the soil was more gravelly and more subject to drouth. The size of the harvested portion of the plots was 40 by 13.6 feet, or one eightieth of an acre, and each treatment was replicated 5 times. The fertilizers were used in such quantities as would furnish 50 pounds of nitrogen per acre. In Table 5 are listed the fertilizers and the mean yield of hay for three years. Only one cutting of grass was made each year. In the first two years the weather was so dry during the latter part of the summer that the rowen crop was a failure. In the third year it was decided, on account of weediness, to plow after the first cutting, and reseed.

TABLE 5.—MEAN ACTUAL AND RELATIVE YIELDS OF DRY MATTER IN HAY FOR THREE YEARS.

Treatment	1932		1933		1934		Mean	
	Actual Yield (Lbs.)	Relative Yield	Actual Yield (Lbs.)	Relative Yield	Actual Yield (Lbs.)	Relative Yield	Actual Yield (Lbs.)	Relative Yield
No nitrogen	1434	100	1821	100	986	100	1414	100
Sodium Nitrate (Champion)	3385	236	3938	216	2337	237	3220	228
Ammonium Sulfate (Arcadian)	3261	227	3494	192	1872	190	2876	203
Calcium Cyanamide (granular)	3000	209	4015	220	1954	198	2990	211
Urea	3096	216	3523	193	1732	176	2784	197

Owing to lack of consistency of these results and to the comparatively short duration of the experiment, it can be considered only as showing a trend in respect to the relative value of the forms of nitrogen used. However, it is quite positive in showing that nitrogen in any form used was very effective in increasing yields. Yields were practically doubled in all cases by the use of a nitrogen fertilizer.

In 1934 samples of grass were taken at intervals of about two weeks from the plots which received different nitrogen fertilizers and analyzed for total nitrogen. At the first sampling the grass was 8 to 10 inches high; at the second, 16 to 20 inches high; and at the third, which was also the time of mowing for hay, 30 to 36 inches high. The results, expressed as percentage of protein, are given in Table 6. These figures show that in the earliest stage of growth the effect of the nitrogen fertilizers in increasing the protein content of the grass was relatively strong, the increase being from about one fourth to one half of the check; that it was considerably less by the time of the second sampling; and that it had practically disappeared at the time of mowing. As between the first and last samplings, there was an increase in the percentage of dry matter, while the protein content decreased correspondingly in the case of the fertilized grass. As the crop approaches maturity the excess nitrogen is apparently used in metabolic processes, and the final effect is reflected in the increased yield of the mature crop. The data are considered inadequate for the drawing of any conclusion as to the relative merits of the several nitrogen carriers in increasing the percentage of protein.

TABLE 6.—EFFECT OF DIFFERENT FORMS OF NITROGEN, USED AS TOP-DRESSING, ON THE DRY MATTER AND PROTEIN CONTENT OF HAY.

Date Sampled	Treatment	Dry Matter (Percent)	Protein in Dry Matter (Percent)
May 21, 1934*	Sodium Nitrate	24.5	20.1
	Ammonium Sulfate	25.2	17.1
	Calcium Cyanamide	24.8	19.6
	Urea	25.9	16.7
	Check	28.8	13.5
June 5, 1934*	Sodium Nitrate	27.1	14.7
	Ammonium Sulfate	29.3	12.4
	Calcium Cyanamide	28.2	14.2
	Urea	28.3	13.1
	Check	28.3	11.4
June 18, 1934**	Sodium Nitrate	46.8	10.3
	Ammonium Sulfate	46.9	9.4
	Calcium Cyanamide	54.4	10.5
	Urea	52.3	9.1
	Check	48.8	9.4

*Plucked samples.

**Samples taken from swath soon after mowing, but probably a little moisture had been lost before sampling.

Summary

Two experiments were conducted in prolonging the life of old mowings by top-dressing with chemical fertilizers. In the first one mixed fertilizers containing different proportions of nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O) were used. The soil was a Merrimac fine sandy loam, somewhat superior for grass to the average soil of this type. The quality and yield of the mowing were improved by fertilizer mixtures high in nitrogen and potash. Little or no benefit was derived from applied superphosphate. A fertilizer having a ratio of N, P_2O_5, and K_2O of about 3:1:2 is recommended for old mowings on soils of this type. On soils of this and closely related types the quality of mixed grass mowings will deteriorate to such an extent in 6 to 8 years, in spite of rational fertilization, that reseeding is desirable.

In another experiment conducted on a similar soil different forms of nitrogen fertilizers were applied as top-dressing. Sodium nitrate, ammonium sulfate, calcium cyanamide, and urea were used in quantities to supply nitrogen at the rate of 50 pounds per acre. The increase due to the fertilizer was a little over 100 percent. The data were inadequate to warrant a conclusion as to the relative merits of the several materials used.

Analysis of samples of grass taken at different stages of maturity showed that the total nitrogen content decreased as maturity advanced. In the earliest stage of growth the nitrogen fertilizers increased the content of nitrogen about one fourth to one half; in the last stage there was little or no difference in the percentage of nitrogen in the fertilized and unfertilized grass.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
4M-9-'35. No. 5534.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 323 July, 1935

The Whole Blood Agglutination Test For Pullorum Disease

By H. Van Roekel and M. K. Clarke

The whole blood test was introduced several years ago in response to a demand for a method of testing less expensive than the standard tube test. This newer test has not proved entirely satisfactory, and the work here described was undertaken to gain more knowledge of the factors which influence its effectiveness and reliability in eliminating pullorum infection from poultry flocks.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE WHOLE BLOOD AGGLUTINATION TEST FOR PULLORUM DISEASE

By H. Van Roekel, Chief of Laboratory, and M. K. Clarke, Laboratory Assistant, Poultry Disease Control[1]

In the control and eradication of pullorum disease among domestic fowl the macroscopic agglutination (tube) test is regarded as a reliable and indispensable means of detecting infected birds. The application of the test along with effective control and eradication measures has led to the establishment of flocks which are free from the disease. This fact has been clearly demonstrated in certain sections which at one time suffered heavy losses from the disease but later enjoyed the benefits derived from pullorum-disease-clean flocks obtained through a supervised and effective testing program.

The testing of flocks for pullorum disease has not received equal encouragement in all sections of this country. This may be attributed to various factors. The cost of the tube method and its inadaptability to the poultry industry in certain sections have been considered to be responsible for the lack of interest and initiative taken in pullorum-disease eradication. Consequently, with a demand for a less expensive method of testing, a field test was introduced by Schaffer, MacDonald, Hall and Bunyea (7) and Coburn and Stafseth (2).

While some investigators and regulatory testing agencies would lead one to believe that this field test is effective in the control and eradication of pullorum disease, others do not accept this view. It is clearly evident, as judged from the investigations reported, that further research is essential to perfect and standardize the technique of the whole blood test in order to increase its efficiency. The purpose of this investigation was to gain a more thorough insight into the factors which influence the effectiveness and reliability of the whole blood test in eliminating pullorum infection from poultry flocks.

HISTORICAL RESUME

Schaffer, MacDonald, Hall and Bunyea (7) report the use of a stained antigen and fresh whole blood in the rapid whole blood test for pullorum disease. The antigen and whole blood are placed and mixed on a glass plate, in the approximate dilution of one part of blood to two or three parts of antigen. A pipette which delivers a drop of antigen, approximately .05 cc., and a wire loop measuring .02 cc. of blood were used. Rotating of the plate was found unnecessary to hasten or bring about agglutination. Reactions which occurred within one minute were regarded as definitely positive, while slower reactions were considered suspicious, and slight reactions appearing after two minutes were disregarded. It was observed that the greater the agglutinating power of the blood, the more rapid the clumping and the larger the clumps. A very fine granulation which is barely visible to the naked eye should be regarded as negative.

Coburn and Stafseth (2) described a whole blood test in which they used an antigen that differs slightly from that employed by Schaffer et al. Equal amounts of antigen and blood measured with standardized pipettes were placed and

---

[1] The authors wish to extend their appreciation to Prof. O. S. Flint for taking the photographs.

mixed on porcelain plates. Readings were made within one to three minutes. Thirty birds were tested with the whole blood and tube methods. The latter method detected 15 negatives, 9 positives, and 6 doubtfuls, while the whole blood test detected 18 negatives and 12 positives.

Welch (10) observed with the whole blood test that in using dry blood smears a great variation in thickness of the smears existed and the amount of blood tested was difficult to determine. The author calls attention to the fact that factors exist which lead to errors. It was observed that birds with low agglutinating titres might not react to the whole blood method. The author concludes that the whole blood test, in spite of its deficiencies, has a place in certain areas when the use of the tube test seems impractical.

Durant (3) in a comparative study of the tube, rapid serum, and whole blood tests found that, among 259 birds tested, 94 were positive to the tube method and 63 were positive to the whole blood test. In a group of 23 birds that were positive to the tube method alone, 18 exhibited lesions of pullorum disease and 13 yielded *S. pullorum*. Among 6 birds that were positive to the whole blood test alone, 4 showed gross lesions and *S. pullorum* was isolated from one. The author suggests that until the rapid test has proved as accurate and dependable as the tube agglutination test, it should not be substituted in campaigns for the eradication of pullorum disease.

Van Roekel, Bullis, Flint, and Clarke (9) report that the tube test was more sensitive in detecting infected birds than the whole blood test. *S. pullorum* was isolated from birds that had not reacted at any time to the whole blood test. Attention is called to factors which exert an influence on the efficiency of the whole blood test. It is emphasized that the whole blood test should be perfected by using a dilution which will be effective and constant in detecting infected birds with low or fluctuating titres.

Barger and Torrey (1) report as follows:—"Using the tube test as an arbitrary standard of perfection in the detection of reactor fowls the whole blood agglutination test has approached an efficiency of nearly 100 percent in the routine testing of farm flocks." Factors such as constant temperature, proper light, suitable equipment to keep out dust, and skill of the operator were regarded as influencing the accuracy of the test. Equal amounts of blood and antigen were placed on a microscopic slide and mixed with a toothpick. The slide was then placed in a specially devised incubator heated by water to maintain a temperature of 25° C. High temperatures were reported to cause rapid evaporation. Frequent rotation of the slides is recommended to hasten agglutination and give a more definite reaction. It is emphasized that partial, flaky, or pseudo-reactions must not be confused with true agglutination.

Graham, Thorp, and Torrey (4) tested 1369 blood specimens with the whole blood and tube methods. The index of agreement of positives and negatives between the standard tube and the rapid whole blood method was 0.848. The interpretations of the 1369 tests were classified as follows:—

Interpretation	*Tube Test*	*Whole Blood Test*
Positive	486	520
Positive and ropy	88	—
Partial	20	22
Trace	3	1
Negative	772	826

It is apparent that the tube test is more sensitive than the whole blood test. However, the authors state that a higher degree of correlation (98 percent) was obtained between the standard tube, rapid serum, and whole blood tests in several flocks subjected to repeated testing. They conclude that these observations indicate that the whole blood test, in properly trained hands, constitutes the simplest and most practical diagnostic procedure yet described for diagnosis of pullorum disease.

Torrey and Graham (8) investigated the problem of doubtful or partial reactors to the whole blood test from the standpoint of pullorum-disease control. It was observed that doubtful reactors were encountered more frequently in heavily infected flocks. In repeated testing of 25 doubtful reactors with the whole blood and tube methods, two types of reactors ("consistent" and "inconsistent") were observed. Among the 25 birds tested, 21 (84 percent) were classified as inconsistent with the whole blood test, and 19 (76 percent) with the tube test. Necropsies of these birds revealed no gross characteristic lesions of the disease. *S. pullorum* was isolated from one bird which was positive to the tube test, except on one test which was doubtful. With the whole blood test, this bird was negative on three tests, doubtful once, and positive twice. These results suggest that the tube test is apparently more sensitive than the whole blood test.

Higgins and Schroeder (5) tested 108 pullets with the tube test (diagnostic dilution not stated) and with five stained antigens for the whole blood test. The results show that the tube test was more sensitive than the whole blood test, yet the authors conclude that very satisfactory agreement in the comparative results was obtained, and that the whole blood test was equal in diagnostic value to the tube agglutination method for detecting infected birds.

An extensive investigation relative to the efficiency of the whole blood test was made by Lubbehusen and Beach (6). Equal amounts of blood and antigen were employed. It was observed that more satisfactory results were obtained by mixing the blood and antigen without subsequent rotating of the plate; incubating the tests for at least six to eight minutes at a constant temperature of 80° C.; and employing adequate light in order to insure accurate interpretation of the tests.

Fourteen groups of birds on five farms were tested, representing a total of 91,449 test birds of which 42,214 were also tested with the tube test. It was emphasized that the efficiency of the whole blood test should not be based on decrease in percentage of reactors, but instead upon comparative results with the tube test and bacteriological findings in birds necropsied. A total of 405 reactors was detected by both methods, of which 217 yielded *S. pullorum* and 188 were negative. The routine whole blood test detected 84 of the 217 infected birds, giving a test efficiency of 38.71 percent. With the whole blood test conducted under laboratory conditions, a test efficiency of 76.5 percent was obtained. The routine tube test (1:25 dilution) detected 216 of the 217 infected birds with a test efficiency of 99.53 percent. The routine tube test failed to detect one infected bird which had given a strong positive reaction with the whole blood test.

The authors state that repeated testing by the whole blood test, although rendering the flock completely negative to that test, failed in each instance to detect all infected fowls or all that would react to the tube test. The whole blood test was more efficient when conducted in the laboratory than when conducted in the field. The number of infected birds in the various flocks was reduced to 1 percent or less by repeated testing with the whole blood method.

It is mentioned that factors peculiar to field conditions apparently are operating which influence the efficiency of the whole blood method. The authors conclude that the efficiency of the whole blood (stained antigen) test will not permit of its exclusive use in a program of pullorum-disease eradication, and that official recognition should be reserved to the tube test results until the whole blood test has been perfected to the point where its efficiency equals that of the tube test.

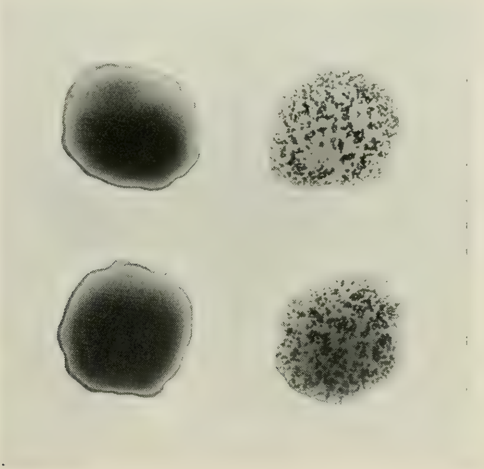


Figure 1. The Whole Blood Agglutination Test.
The mixtures in the squares on the left show a negative reaction; the mixtures on the right show a positive reaction.

TECHNIQUE OF TESTING METHODS USED

Whole Blood Method. The antigen employed was prepared according to the procedure recommended by U. S. B. A. I., U. S. Patent No. 1,816,026, with a slight modification. The organisms were cultivated on nutrient meat extract agar instead of meat infusion agar. The pullorum antigen strains selected by the Antigen Committee of the Pullorum Conference of the Northeastern States were employed. An improvised testing apparatus was used, consisting of a wooden box, insulated with Celotex and lined with metal. The antigen and blood were placed on a glass slide which fitted into a removable frame covered with glass to serve as a protection against dust and to retain the heat. A temperature between 85° and 95° F. was maintained by two (paint coated) electric bulbs, controlled by a thermostat. An electric bulb provided a sufficient and constant supply of light. The antigen was placed on the glass slide with a special pipette, which delivered approximately .045 cc. The blood was measured with a wire loop which conveyed approximately 0.35 to .04 cc. The blood was added to the antigen and mixed with the wire loop. At definite intervals the frame holding the test plate was rotated. The results of the tests were recorded following three minutes' incubation.

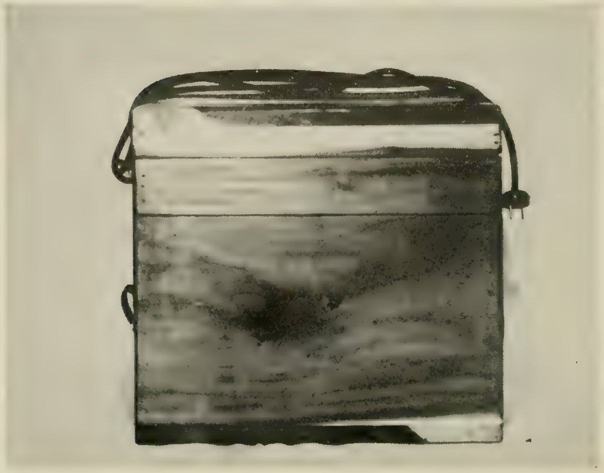


Figure 2. An Electrically Heated and Lighted Apparatus Used for the Whole Blood Agglutination Test.

Size 15 by 15 inches, by 14 inches deep. Construction consists of a wooden frame lined with Celotex and metal.

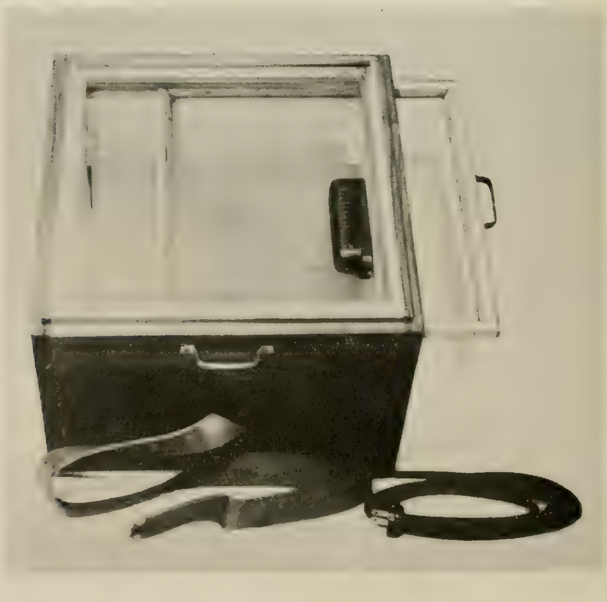


Figure 3. Same Apparatus with Cover Removed.

The test plate (size 12 by 12 inches) slides into a removable frame which is covered with glass.

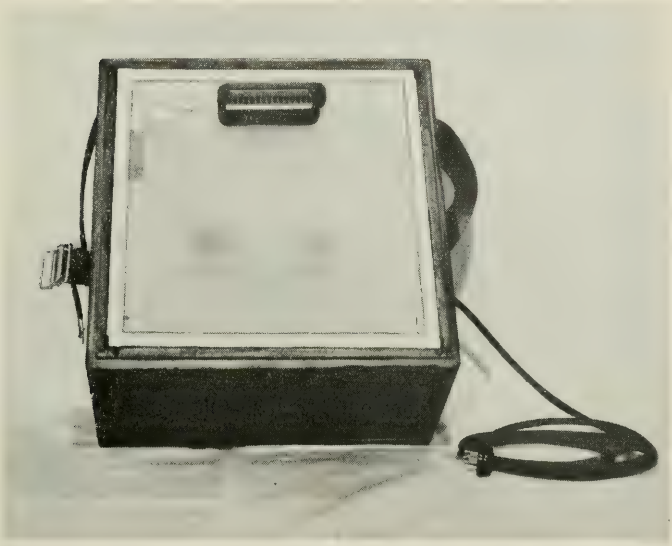


Figure 4. Same Apparatus as in Figure 3 with the Test Plate Holder Removed. The thermostat and frosted glass plate which rests on shoulders are exposed. The frosted glass plate permits uniform heat distribution.

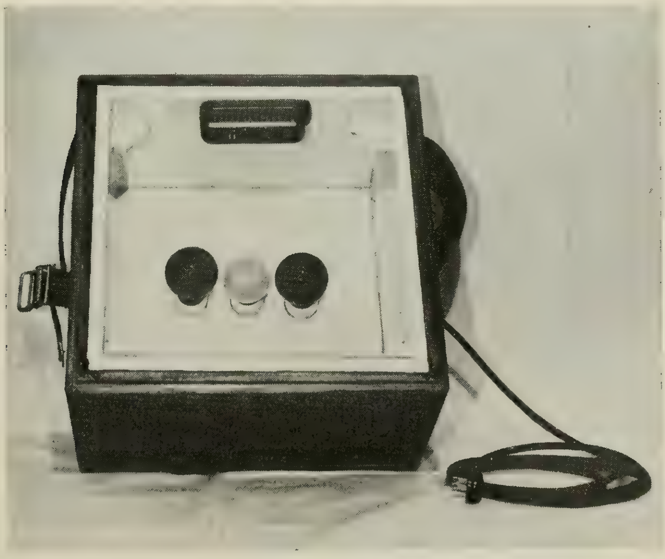


Figure 5. Same Apparatus as in Figure 4 with the Frosted Glass Plate Removed, Exposing the Two Dark Heat Bulbs and the White Light Bulb.

At the outset of the investigation a testing apparatus was employed which was heated with tempered water. The temperature of the test plate was maintained between 80° and 95° F. The apparatus was not equipped with artificial light.

Tube Method. The technique of the tube agglutination method was identical with that described in the Standard Methods (11) of Diagnosis for Pullorum Disease. A diagnostic dilution of 1:25 and an incubation period of 24 hours at 37° C. were employed.

MISCELLANEOUS EXPERIMENTS

Since standardization of the tube test has brought forth more uniform and reliable results in pullorum-disease testing, it is only logical to assume that the same would hold true if the technique of the whole blood test were perfected and standardized. It is apparent that there is a great lack of uniformity in the manner in which the whole blood test is conducted at the present time. Investigations have revealed several factors that appear to play an important role in the accuracy of the test. The need for further investigation of these influencing factors is apparent, since various investigators disagree on certain phases of the whole blood test. Increased efficiency of this method cannot be expected until each problem has been analyzed and solved. This naturally requires a scientific approach in order to determine the true significance of the different factors influencing the accuracy of the test.

In the development and standardization of the tube test, the serum-antigen dilution factor was found to play an important role in the successful elimination of infected birds. At first the fact was not appreciated that some infected birds may exhibit low titres or intermittent reactions. Such birds would be overlooked with a serum–antigen dilution above the serum agglutination titre. It follows that with the use of the whole blood test the blood-antigen dilution should receive further study. Measurements of blood and antigen have been lacking in uniformity and constancy in the methods described.

In a few miscellaneous experiments an effort was made to determine what variation in the quantities of blood and antigen might exist in the whole blood test and its influence on the agglutination reaction.

Antigen Measurements. A special pipette, simulating a medicine dropper, was used for measuring the antigen by drops. Realizing that the size of the drops might vary, a series of measurements was made to determine the amount of antigen and its variation in the drops. Table 1 shows that in a total of 100 drops the quantity of antigen varied from .042 to .055 cc. The majority of the drops ranged from .044 to .047 cc., and the average quantity for the 100 drops was .04709 cc. While these measurements were made in the laboratory under most favorable conditions, it is likely that the variation might be even greater under field conditions, when several operations are carried on simultaneously and at greater speed.

TABLE 1.--VARIATION IN MEASUREMENTS OF ANTIGEN.

Quantities of Antigen (cc. per drop)	*Number of Drops*
.042	2
.043	4
.044	17
.045	19
.046	10
.047	16
.048	3
.049	6
.05	4
.051	6
.052	4
.053	2
.054	5
.055	2
	100

Whole Blood Measurements. The whole blood was measured with a wire loop having a 6 mm. diameter. With the wire loop the blood was collected from the wing vein puncture and measured with a graduated pipette. It was impossible to obtain uniform loopfuls of blood from each bird, especially when the blood did not escape freely or did not accumulate to such an extent that the loop would fill and withdraw the proper amount of blood. Table 2 shows that greater variation was found in 100 blood measurements than in the antigen measurements. While the majority of the measurements ranged from .03 to .045 cc., the minimum and maximum amounts were .022 and .05 cc., respectively, a range of .028 cc. The average for the 100 measurements was .03541 cc. It is reasonable to suspect that such a variation would influence the degree of agglutination reaction, especially in low-titre birds.

TABLE 2.--VARIATION IN MEASUREMENTS OF FRESH WHOLE BLOOD.

Quantities of Whole Blood (cc. per wire loop)	*Number of Loopfuls*
.02 —.024	2
.025—.029	7
.03 —.034	28
.035—.039	31
.04 —.044	30
.045—.05	2
	100

Influence of Blood–Antigen Dilution on Degree of Agglutination. In this experiment a number of positive-reacting birds were employed. The blood samples were collected into tubes containing 10 percent sodium citrate solution in amounts (1 part sodium citrate and 14 parts blood) to prohibit coagulation. The drop method was used for measuring the antigen, while a graduated pipette was employed to measure the citrated whole blood. The amounts of blood tested were

.04, .02, .01, .005, and .001 cc. The tests were made at a temperature of 78° to 80° F., and readings were recorded after a 3-minute incubation period. Table 3 shows the results of testing 10 samples with the whole blood test. The results with the tube test represent the serum titre of the birds four days prior to the time the samples were collected for the whole blood test. Six of the ten samples were tested twice. On second test the reaction did not appear as strong as the first. It may be seen that the degree of reaction with the whole blood test correlates in a measure with the degree of reaction and titre observed with the tube method. While a reaction was obtained in all samples tested, it was extremely weak in two cases and might have been overlooked under field conditions. It is of interest to note that an amount of blood as small as .001 cc. is able to produce a reaction.

TABLE 3.--INFLUENCE OF BLOOD–ANTIGEN DILUTION
ON DEGREE OF AGGLUTINATION.

Bird No.	Trial	Whole Blood Test Amounts of Citrated Blood (cc.) .04	.02	.01	.005	.001	Serum Agglutination Titre (Tube Method) 10	20	40	80	160	320	640	1280	2560
92002	1st	2	1	0	0	—									
	2nd	1	0	0	0	—	3	2	1	0					
53747	1st	1	4	4	4	1									
	2nd	4	3	4	3	1	4	4	4	4	3	2	1	1	0
91290	1st	4	2	1	0	—									
	2nd	3	1	1	0	—	3	2	1	0					
91932	1st	3	1	1	0	—									
	2nd	3	1	0	0	—	4	3	2	1	0				
90993	1st	4	4	3	2	1									
	2nd	4	4	3	1	0	4	4	3	2	1	0			
91920	1st	2	1	1	0	—									
	2nd	3	1	0	—	—	4	3	2	1	0				
91040	1st	1	1	0	0	—	3	2	1	0					
91822	1st	4	4	4	4	2	4	4	4	4	3	2	1	0	
91963	1st	4	3	2	1	0	4	3	2	1	0				
51007	1st	3	1	0	—	—	4	3	2	1	0				

Legend

Tube Method: 4—complete agglutination
3—incomplete agglutination
2—partial agglutination
1—slight agglutination
0—no agglutination

Whole Blood: 4—numerous and large clumps developing rapidly
3—numerous and medium clumps developing quite rapidly
2—fine clumps and less numerous developing rapidly or slowly
1—very fine clumps and few in number
0—no agglutination

In a second trial, five positive birds were tested with both the whole blood and the tube methods, as shown in Table 4. Each sample was tested twice with the whole blood test with practically the same results. The citrated as well as the uncitrated blood serum was tested with the tube method, with no significant differences in titre. Three birds in this group (91040, 91963, and 90993) were

TABLE 4.--INFLUENCE OF BLOOD–ANTIGEN DILUTION ON DEGREE OF AGGLUTINATION.*

Bird No.	Trial	Whole Blood Test Amounts of Citrated Blood (cc.) .04	.02	.01	.005	.001	Serum Agglutination Titre (Tube Method) 10	20	40	80	160	320	640	1280	2560
91040	1st	1	1	0	—	—									
	2nd	1	1	0	—	—	4	3	2	1	0				
91963	1st	4	4	2	1	0									
	2nd	4	4	2	1	0	4	4	4	4	3	1	0		
90993	1st	4	4	3	2	0									
	2nd	4	4	3	1	0	4	4	4	4	4	2	1	0	
90969	1st	1	0	0	—	—									
	2nd	1	0	0	—	—	4	3	2	1	0				
91941	1st	2	0	0	—	—									
	2nd	1	0	0	—	—	4	4	2	0					

*Refer to legend of Table 3.

tested two weeks previously, and the results are listed in Table 3. It may be seen that the reactions obtained at both trials agree very closely.

EXPERIMENTAL TESTING IN COMMERCIAL FLOCKS

In determining the true value of the whole blood test as a diagnostic means of detecting "carriers" of pullorum infection, it was deemed expedient to select infected flocks of a desirable size which could be tested with the whole blood test at frequent intervals until negative. After no more reactors could be detected with the whole blood test, the flock was to be check-tested with the standard tube method. All birds that showed reactions of interest from a diagnostic point of view were either retained in quarantine on the premises or taken to the laboratory for further observation.

The scope of this investigation also included a determination of the comparative efficiency of the whole blood and standard tube methods, by using both methods simultaneously in eliminating pullorum-disease "carriers" from an infected flock through repeated testing. Likewise in this phase of the investigation, birds which gave reactions of diagnostic interest were subjected to further study.

Results

Two known infected flocks (A and B) were selected and tested with the whole blood test to determine its efficiency as a diagnostic means of detecting pullorum-disease-reacting birds. The original plan was to test the flocks at approximately monthly intervals until no reactors appeared and then to check test them with the standard tube test. Unfortunately this plan could not be followed, due to the fact that reactors continued to appear on retest, which threatened to delay the hatching season; hence the flock owners requested that the whole blood test be supplemented with the standard tube test in order to hasten eradication of the infected birds in the flock. At the completion of the test all reactors were check-tested with the whole blood test, and blood samples were collected for the standard tube test.

As mentioned previously birds which gave agglutination reactions but could not be classified as definite positive reactors, were either retained in quarantine on the premises or submitted to the laboratory for further study. All other reactors were eliminated immediately for slaughter. The pens were cleaned and disinfected after each test if conditions permitted.

Flock A. This flock consisted of 1187 birds which were tested in October, 1934. The testing apparatus heated by tempered water was used in this test. Fourteen reactors were detected on the first test. The testing results of both methods and the disposal of the reactors are presented in Table 5.

TABLE 5.--TESTING RESULTS WITH REACTORS IN FLOCK A.

Bird No.	Reaction with W. B. T.	Routine Tube Test 1:25	Reaction with Tube Method Dilution							Disposal
			10	20	40	80	160	320	640	
93171	1	2	3	2	1	1	0	0	0	Quarantine
93177	1	0	2	1	1	0	0	0	0	
93247	1	1	2	2	1	1	0	0	0	
93293	1	0	1	0	0	0	0	0	0	
93372	1	1	Unsatisfactory							Laboratory
93394	1	1	3	2	1	1	0	0	0	
93527	1	4	4	4	4	3	0	0	0	
93550	1	4	4	4	2	0	0	0	0	
93523	2	4	4	4	4	3	0	0	0	
93507	3	4	4	4	3	1	0	0	0	Slaughter
93522	3	4	4	4	4	4	1	0	0	
93529	4	4	4	4	4	4	4	1	0	
93539	4	4	4	4	4	4	4	1	0	
93547	4	4	4	4	4	4	4	2	0	

The blood of three birds produced delayed clumping or agglutination which was impossible to distinguish from a true partial reaction. On the strength of the tardiness of the reaction the birds were not removed from the flock.

The second test was conducted in November 1934, and revealed two strong reactors among 1157 birds. Of the four doubtful reactors detected on the first test and held in quarantine, three gave slight reactions on the second test and one was negative. These birds were sold before the next test was conducted.

In view of the fact that the infection apparently was limited to one pen of birds, only this group of birds was tested on December 13, 1934. The testing apparatus electrically heated and lighted was used in this and the subsequent test. Among the 37 birds one strong reactor was detected.

In January the entire flock (1067 birds) was tested with both the whole blood and tube methods in order to expedite eradication. Two birds reacted with both methods and seven reacted suspiciously only with the tube test. One of the two reactors (93546) gave a partial reaction with the whole blood test; but in two check tests with this method, slightly suspicious and negative reactions, respectively, were obtained. With the tube test the serum of this bird gave a "4" reaction in the 1:25 dilution and on dilution test revealed a titre of 1:320. This bird was submitted to the laboratory, while the seven reactors to the tube test were placed in quarantine. At the completion of this test the owner was advised to dispose of the small group of birds which had been maintained in quarantine and continued to reveal positive reactors.

In February the entire flock was retested with the tube test and no reactors were detected. This group of birds was not further tested since it had passed two consecutive negative tests with the tube method. Of the seven suspicious birds detected on the previous test two had been sold and the remaining five were negative.

TABLE 6.--SUMMARY OF TESTS--FLOCK A.

Date	*Testing Method*	*Number of Birds*	*Number of Reactors*	
October	Whole Blood	1187	14	
November	Whole Blood	1157	2	
December	Whole Blood	37	1	
January	Whole Blood and Tube	1067	9	7 tube test 2 both tests
February	Tube	1000	0	
Total		4448	26	

Six of the 26 reactors were submitted to the laboratory for further study. The observations for each bird are presented in Table 7.

In summarizing the testing results for Flock A, it may be stated that the whole blood test detected the majority of infected birds on the first test, but positive reactors continued to appear by the use of this method for four consecutive tests. Whether the whole blood test would have been capable of eliminating all infected birds from the flock by further testing the unit of birds in which reactors continued to appear, remains a question. To what extent the persistence of infection was influenced by the degree of sensitivity of the whole blood test is impossible to determine from the results. Delayed weak reactions, as well as doubtful reactions occurring within the reading time were observed. As may be seen from the agglutination and necropsy results, the reaction with the whole blood test might be very weak or even negative, whereas with the tube test a complete reaction was exhibited in the 1:25 dilution. Bacteriological examination of such reactors would yield *S. pullorum* in some instances. Weak or doubtful reactions appeared identical for birds that proved to be either negative or positive on bacteriological examination. Birds exhibiting a low titre with the tube test generally gave a negative, weak or doubtful reaction with the whole blood test. As the serum titre fluctuated within a definite range, the reaction of the latter method might also fluctuate. Birds with high titres usually produced rapid and distinct reactions with the whole blood method, although in one instance bird 93546 reacted indifferently but its serum titre was as great as that of some birds which gave consistent strong reactions. The failure to isolate *S. pullorum* from this bird may be attributed to the examination or to the fact that the infection was of recent origin, and no definite gross foci had been established.

TABLE 7.--FURTHER OBSERVATIONS ON SIX REACTORS IN FLOCK A.

Bird No.	Date Detected	Routine Tube Test 1:25	Date of Test	Tube Test							Whole Blood Test	Date of Necropsy	*S. pullorum* Isolated
				Dilution									
				10	20	40	80	160	320	640			
93372	10/8/34	1	10/8/34	U	U	U	1	1	0	0	1	10/30/34	Negative
			10/17/34	0	0	0	0	0	0	0	1		
			10/23/34	0	0	0	0	0	0	0	0		
			10/27/34	NT							0		
			10/30/34	0	0	0	0	0	0	0	0		
93394	10/8/34	1	10/8/34	3	2	1	1	0	0	0	1	10/30/34	Negative
			10/17/34	1	0	0	0	0	0	0	0		
			10/23/34	1	0	0	0	0	0	0	0		
			10/27/34	NT							0		
			10/30/34	2	1	1	0	0	0	0	0		
93523	10/9/34	4	10/9/34	4	4	4	3	0	0	0	2	10/30/34	Positive
			10/17/34	4	4	3	1	0	0	0	2		
			10/23/34	4	4	4	1	0	0	0	3		
			10/27/34	NT							0		
			10/30/34	4	4	2	1	0	0	0	1		
93527	10/9/34	4	10/9/34	4	4	4	3	0	0	0	1	10/30/34	Positive
			10/17/34	4	4	3	2	0	0	0	2		
			10/23/34	4	4	4	1	0	0	0	1		
			10/27/34	NT							1		
			10/30/34	4	4	4	2	1	0	0	2		
93550	10/9/34	4	10/9/34	4	4	2	0	0	0	0	1	12/21/34	Positive
			10/17/34	3	2	1	0	0	0	0	1		
			10/23/34	3	2	1	0	0	0	0	2		
			10/27/34	4	4	4	2	0	0	0	2		
			10/30/34	4	4	4	1	0	0	0	3		
			11/7/34	4	4	3	1	0	0	0	4		
			11/10/34	4	3	1	0	0	0	0	4		
			11/15/34	4	4	3	2	0	0	0	4		
			11/20/34	4	4	3	1	0	0	0	4		
			11/30/34	4	4	4	4	3	0	0	4		
			12/13/34	4	4	4	4	3	2	0	4		
			12/19/34	4	4	4	4	3	1	0	4		
			12/21/34	4	4	4	4	3	2	0	NT		
93546	1/4/35	4	1/4/35	4	4	4	3	1	1	0	3	1/9/35	Negative
			1/9/35	4	4	4	3	1	1	0	2		

U—unsatisfactory test
NT—not tested

Flock B. On October 2 and 3, 1934, 826 birds were tested with the whole blood test, using the apparatus equipped with the water heater. The testing operations were conducted in the same manner as described for Flock A. The first test represents only a partial flock test since not all the birds had been taken in from range. Among the 826 birds tested, 29 reactors were detected. The blood of one bird (92237) exhibited a delayed reaction which was observed only after the bird had been returned to the flock. This bird was not regarded as a reactor and will be mentioned again in the discussion of subsequent tests. Of the 29 reactors, six were submitted to the laboratory for further study and the remainder were slaughtered.

On October 31 and November 2, 1934, 1120 birds (349 first test and 771 second test) were tested by the whole blood method. Eleven reactors were detected among the 349 first-test birds. Again one bird (99017) gave a delayed reaction but was not removed from the flock until a later test. Of the eleven reactors, five were submitted to the laboratory and the remainder were slaughtered. Among the 771 birds tested for the second time, two reactors were detected and removed for slaughter.

On December 10 and 11, 1934, 976 birds were tested and revealed ten reactors. The electrically equipped testing apparatus was used on this and subsequent tests. The blood of two birds (99100 and 92237) gave delayed reactions. One, 92237, reacted in a similar manner on the first test, but did not react on the second test. Three reactors (99255, 99017 and 99087) were submitted to the laboratory. Bird number 99017 gave a delayed reaction with the whole blood method on the second test. A small group of birds, approximately 80 in number, which had passed two negative tests and were confined in a separate building were not tested at this time.

On January 14 and 15, 1935, the entire flock, consisting of 989 birds, was tested and revealed four reactors (99052, 99130, 99239 and 99302). Four birds (99039, 99097, 99100 and 92297) gave delayed reactions. Bird 99100 reacted in a similar manner on the previous test, but was permitted to remain in the flock on the strength of the type of reaction. One (99130) of the four reactors was submitted to the laboratory.

Since reactors continued to appear in two pens and the owner was desirous of eliminating the infection in the shortest possible time, the birds in these two pens were retested at two-week intervals and the whole blood test was supplemented with the standard tube test.

On January 28, 1935, a total of 292 birds was tested. Nine birds were detected as reactors: two (99100 and 99186) reacting to both methods, one (99272) to the whole blood test, and six (91923, 99039, 99077, 99153, 99181 and 99250) to the tube test. Seven of the nine reactors were submitted to the laboratory. Of the other two reactors, one (99077) died shortly after the test and the other (91923) remained on the premises but gave a negative reaction to both methods on the next test.

On February 11, 1935, the entire flock was tested with both methods and no reactors were detected. Nine delayed reactions were observed with the whole blood test in one pen of birds which had never revealed reactors. On subsequent test these delayed reacting birds were negative.

On February 25, 1935, no reactors were detected among birds tested on January 28. Approximately two weeks later (March 11 and 12) the entire flock was tested with negative results. No further testing was conducted, since the entire flock had passed two consecutive negative tests at least one month apart.

TABLE 8.--SUMMARY OF TESTS--FLOCK B.

Date of Test	*Number of Birds*	*Number of Reactors*
October 2 and 3, 1934	826	29
October 31 and November 2	1120	13
December 10 and 11	976	10
January 14 and 15, 1935	989	4
January 28	292	9 { 1 W. B. T. 2 both tests 6 tube test
February 11 and 12	851	0
February 25	204	0
March 11	795	0
Totals	6053	65

The agglutination studies and necropsy results on the 22 reactors submitted to the laboratory are shown in Table 9.

TABLE 9.--FURTHER OBSERVATIONS ON TWENTY-TWO REACTORS IN FLOCK B.

Bird No.	Date Detected	Routine Tube Test 1:25	Date of Test	Tube Test Dilution 10	20	40	80	160	320	640	1280	Whole Blood Test	Date of Necropsy	*S. pullorum* Isolated
92043	10/2/34	3	10/2/34	4	4	3	1	0	0	0	0	3	10/22/34	Positive
			10/13/34	4	4	4	2	1	0	0	0	3		
			10/17/34	4	4	3	2	0	0	0	0	3		
			10/22/34	4	3	3	2	0	0	0	0	NT		
92100	10/2/34	4	10/2/34	4	3	2	0	0	0	0	0	4	10/22/34	Positive
			10/13/34	4	4	4	4	3	1	0	0	4		
			10/17/34	4	4	4	4	3	1	0	0	4		
			10/22/34	4	4	4	3	2	1	0	0	4		
92308	10/2/34	4	10/2/34	4	4	3	1	0	0	0	0	2	10/22/34	Positive
			10/13/34	4	4	4	1	3	2	1	0	4		
			10/17/34	4	4	4	4	3	1	0	0	4		
			10/22/34	4	4	4	3	2	1	1	0	4		
92364	10/2/34	4	10/2/34	3	2	1	0	0	0	0	0	4	10/22/34	Positive
			10/13/34	4	4	4	4	3	1	0	0	4		
			10/17/34	4	4	4	4	3	1	0	0	4		
			10/22/34	4	4	4	3	2	0	0	0	4		
92368	10/2/34	4	10/2/34	4	4	3	1	0	0	0	0	1	12/26/34	Positive
			10/13/34	4	4	3	1	0	0	0	0	2		
			10/17/34	4	4	2	1	0	0	0	0	2		
			10/23/34	3	2	1	1	0	0	0	0	1		
			10/27/34	3	2	1	0	0	0	0	0	0		
			10/30/34	4	3	2	1	0	0	0	0	0		
			11/7/34	4	3	3	2	1	0	0	0	4		
			11/10/34	4	3	2	1	0	0	0	0	4		
			11/15/34	4	4	3	2	1	0	0	0	4		
			11/20/34	4	4	4	4	2	0	0	0	3		
			11/30/34	4	4	3	2	1	0	0	0	2		
			12/13/34	4	4	4	2	0	0	0	0	2		
			12/19/34	4	4	4	3	2	0	0	0	4		
			12/26/34	4	4	4	4	2	0	0	0	4		
92517	10/2/34	2	10/2/34	4	4	2	0	0	0	0	0	1	12/26/34	Positive
			10/13/34	4	4	2	1	0	0	0	0	2		
			10/17/34	4	4	4	1	0	0	0	0	1		
			10/23/34	4	3	2	1	0	0	0	0	3		
			10/27/34	4	4	4	2	0	0	0	0	2		
			10/30/34	4	4	1	1	0	0	0	0	0		
			11/7/34	4	3	2	0	0	0	0	0	1		
			11/10/34	3	2	1	0	0	0	0	0	0		
			11/15/34	4	3	2	1	0	0	0	0	2		
			11/20/34	4	3	2	0	0	0	0	0	1		
			11/30/34	4	4	4	0	0	0	0	0	1		
			12/13/34	4	4	3	0	0	0	0	0	1		
			12/19/34	4	4	4	2	0	0	0	0	2		
			12/26/34	4	4	4	3	0	0	0	0	2		
99017	12/11/34	NT	12/11/34	4	4	4	2	1	0	0	0	1	12/31/34	Positive
			12/19/34	4	4	4	4	3	1	0	0	4		
			12/26/34	4	4	4	4	3	1	0	0	2		
			12/31/34	4	4	4	3	2	0	0	0	2		
99039	1/28/35	2	1/28/35	NT								0	3/2/35	Positive
			2/5/35	4	4	4	1	0	0	0	0	0		
			2/15/35	4	4	4	4	3	0	0	0	1		
			2/20/35	4	4	4	3	1	0	0	0	1		
			2/28/35	4	4	4	1	0	0	0	0	1		
99072	10/31/34	4	10/31/34	4	4	4	3	1	0	0	0	3	12/27/34	Positive
			11/10/34	4	4	4	2	2	1	1	0	4		
			11/15/34	4	4	4	4	3	3	2	1	4		
			11/20/34	4	4	4	4	4	2	1	0	4		
			11/30/34	4	4	4	4	4	2	1	0	4		
			12/13/34	4	4	4	4	3	2	1	0	4		
			12/19/34	4	4	4	4	4	3	2	0	4		
			12/26/34	4	4	4	4	4	4	2	0	3		
99087	12/11/34	NT	12/11/34	4	3	3	1	0	0	0	0	2	12/31/34	Positive
			12/19/34	4	4	4	2	0	0	0	0	3		
			12/26/34	4	4	4	4	3	0	0	0	4		
			12/31/34	4	4	4	3	1	0	0	0	4		
99100	1/28/35	1	1/28/35	NT								3	3/2/35	Positive
			2/5/35	4	4	4	4	3	1	0	0	4		
			2/15/35	4	4	4	3	2	1	0	0	2		
			2/20/35	4	4	4	3	2	0	0	0	2		
			2/28/35	4	4	4	2	1	0	0	0	2		

TABLE 9.--CONTINUED.

Bird No.	Date Detected	Routine Tube Test 1:25	Date of Test	Tube Test Dilution								Whole Blood Test	Date of Necropsy	*S. pullorum* Isolated
				10	20	40	80	160	320	640	1280			
99107	10/31/34	4	10/21/34	4	4	3	2	0	0	0	0	4	2/5/35	Positive
			11/10/34	4	2	1	0	0	0	0	0	4		
			11/15/34	4	3	2	1	0	0	0	0	3		
			11/20/34	3	3	2	1	1	0	0	0	2		
			11/30/34	4	4	4	3	3	0	0	0	4		
			12/13/34	4	4	4	4	4	3	3	1	4		
			12/19/34	4	4	4	4	3	3	3	2	4		
			12/26/34	4	4	4	4	4	4	3	2	4		
			12/31/34	4	4	4	4	3	3	3	3	4		
			1/8/35	4	4	4	4	3	3	3	3	4		
			1/16/35	4	4	4	4	4	4	4	4	4		
			1/23/35	4	4	4	4	4	4	4	4	4		
			1/31/35	4	4	4	3	3	3	2	2	4		
			2/5/35	4	4	4	4	4	4	3	2	4		
99130	1/15/35	NT	1/15/35	NT								2	2/5/35	Positive
			1/16/35	4	4	3	2	0	0	0	0	2		
			1/23/35	4	4	4	2	0	0	0	0	3		
			1/31/35	4	4	4	3	1	0	0	0	4		
			2/5/35	4	4	3	1	0	0	0	0	3		
99153	1/28/35	1	1/28/35	NT								0	3/2/35	Negative
			2/5/35	1	1	0	0	0	0	0	0	0		
			2/15/35	0	0	0	0	0	0	0	0	0		
			2/20/35	0	0	0	0	0	0	0	0	0		
			2/28/35	0	0	0	0	0	0	0	0	0		
99181	1/28/35	4	1/28/35	NT								0	3/1/35	Positive
			2/5/35	4	4	4	1	0	0	0	0	0		
			2/15/35	4	4	3	2	0	0	0	0	1		
			2/20/35	4	4	4	2	0	0	0	0	2		
			2/28/35	4	4	4	4	2	0	0	0	2		
99186	1/28/35	4	1/28/35	NT								2	2/5/35	Positive
			1/31/35	4	4	4	3	1	0	0	0	2		
			2/5/35	4	4	4	4	2	0	0	0	4		
99188	10/31/34	4	10/31/34	4	4	4	3	1	0	0	0	3	12/13/34	Positive
			11/10/34	4	4	3	2	1	0	0	0	3		
			11/15/34	4	4	4	3	1	0	0	0	4		
			11/20/34	4	4	4	3	2	0	0	0	3		
			11/30/34	4	4	4	4	1	0	0	0	4		
			12/13/34	4	4	4	3	1	0	0	0	3		
99198	10/31/34	4	10/31/34	4	4	4	3	1	0	0	0	2	2/5/35	Positive
			11/10/34	4	3	2	1	0	0	0	0	2		
			11/15/34	4	3	2	1	0	0	0	0	2		
			11/20/34	4	4	4	1	0	0	0	0	0		
			11/30/34	4	4	4	2	0	0	0	0	0		
			12/13/34	4	4	4	3	1	0	0	0	2		
			12/19/34	4	4	4	3	2	0	0	0	4		
			12/26/34	4	4	4	4	3	1	0	0	3		
			12/31/34	4	4	4	4	3	1	1	0	3		
			1/8/35	4	4	4	4	4	3	1	0	4		
			1/16/35	4	4	4	4	4	3	2	1	4		
			1/23/35	4	4	4	4	4	4	2	1	4		
			1/31/35	4	4	4	4	4	3	3	2	4		
			2/5/35	4	4	4	4	4	3	2	1	4		
99226	10/31/34	4	10/31/34	4	4	4	3	1	0	0	0	1	12/13/34	Positive
			11/10/34	4	3	2	1	0	0	0	0	2		
			11/15/34	4	4	3	2	1	0	0	0	2		
			11/20/34	4	4	4	4	3	0	0	0	4		
			11/30/34	4	4	4	4	4	2	1	0	4		
			12/13/34	4	4	4	4	4	3	2	2	4		
99250	1/28/35	1	1/28/35	NT								0	3/1/35	Negative
			2/5/35	4	2	1	0	0	0	0	0	0		
			2/15/35	3	2	1	0	0	0	0	0	0		
			2/20/35	3	1	0	0	0	0	0	0	0		
			2/28/35	4	3	1	0	0	0	0	0	0		
99255	12/10/34	NT	12/10/34	4	4	3	1	0	0	0	0	3	12/31/34	Positive
			12/19/34	4	4	3	1	0	0	0	0	3		
			12/26/34	4	4	2	0	0	0	0	0	0		
			12/31/34	4	3	1	0	0	0	0	0	NT		
99272	1/28/35	0	1/28/35	0	0	0	0	0	0	0	0	2	2/22/35	Negative
			1/31/35	0	0	0	0	0	0	0	0	0		
			2/5/35	0	0	0	0	0	0	0	0	0		
			2/15/35	0	0	0	0	0	0	0	0	0		
			2/20/35	0	0	0	0	0	0	0	0	0		

NT—not tested.

The results show that no reactors appeared after all the birds had been subjected to four tests with the whole blood method, although the birds tested on January 28 (fourth test) were also tested with the standard tube method which detected six additional reactors, two of which proved to be infected. The results obtained in Flock B are of very great interest in that delayed reacting birds are of significance in eradicating the disease from a flock. Some birds exhibited delayed reactions consistently or intermittently on subsequent tests, whereas others became either distinctly negative or positive. Delayed reactions were exhibited by 15 birds during the testing of this flock: two (99017 and 99100) were later detected as positive reactors, whereas the remaining 13 became negative to the whole blood test. Of this latter group one (99039) was later detected with the tube test and found infected on necropsy. (*S. pullorum* was isolated from pericardial fluid, liver, spleen, peritoneum, ovary, and abdominal cyst). Bird 99181 was also detected on the fourth test with the tube method but did not react with the whole blood test. This bird gave a doubtful reaction with the whole blood method at a later date and at necropsy *S. pullorum* was isolated from the pericardial fluid, liver, spleen, peritoneum and ovary. Among the 22 reactors examined at the laboratory, *S. pullorum* was recovered from 19. Bacteriological examination of two of the delayed reacting birds revealed that *S. pullorum* was isolated from the ovary and abdominal cyst in one (99017), and from the pericardium, liver, peritoneum, ovary, and abdominal cyst in the other (99100). A great fluctuation in the degree of reaction with the whole blood test was observed in some birds that were tested at short intervals. Infrequently this fluctuation could be correlated with the variation in serum titre. One bird (99272), reacting to the whole blood test only when submitted to the laboratory, did not react to either method on subsequent tests, and *S. pullorum* was not isolated. Two birds reacting only to the tube test did not reveal the organism on bacteriological examination.

Flock C. This flock had not revealed reactors for two consecutive years. However, on initial test with the standard tube method 17 reactors were detected among 445 birds tested. This flock appeared satisfactory for the purpose of comparative testing with the whole blood and standard tube methods. Upon recognition of infection in the flock, the owner was requested not to dispose of reactors until after the first comparative test.

On October 24 and 25, 1934, the entire flock was tested with the whole blood test and standard tube method, using the testing apparatus with the improvised water heating system. A total of 1053 birds was tested and revealed 40 reactors—19 with the tube method, 2 with the whole blood test, and 19 with both methods. The reactors were treated in the following manner:—

	Slaughter	*Quarantine*	*Laboratory*	Total
Birds reacting to tube test only...	0	16	3	19
Birds reacting to W. B. T. only...	0	0	2	2
Birds reacting to both methods ...	10	4	5	19
Total......................	10	20	10	40

On November 28, 1934, a total of 732 birds was tested with both methods and only three birds gave a doubtful reaction with the tube method. These birds (95825, 95829 and 96027) were submitted to the laboratory for further study. A part of the flock, representing old hens which had been non-reacting for two seasons, was not tested. Among the 20 reacting birds held in quarantine, 18 survived the second test and revealed three reactors (one with both methods and two with the tube test). Unfortunately the owner failed to send these birds to the laboratory.

The third test was conducted on January 7, 1935, when the entire flock (894 birds) was tested with the tube test only and no reactors were detected at this time. No further testing was conducted in this flock.

TABLE 10--SUMMARY OF TESTS--FLOCK C.

Date of Test	*Number of Birds*	*Number of Reactors*	
October 24 and 25, 1934	1053	40	19 tube test 2 W. B. T. 19 both tests
November 28	732	3	tube test
	18 (reactors in quarantine)	3	2 tube test 1 both tests
January 7, 1935	894	0	
Total	2697	46	

The results of the agglutination tests and necropsies of the 13 reacting birds submitted to the laboratory are shown in Table 11.

S. pullorum was isolated from 5 of the 13 reactors submitted to the laboratory. Four birds (92817, 92842, 95928, and 95842) gave delayed weak reactions with the whole blood test. Birds 92817 and 92842 did not react with the tube method on initial test, while the sera of birds 95928 and 95842 gave a strong reaction in the 1:25 dilution. *S. pullorum* was isolated from the latter two birds. Bird 96027 gave a partial reaction with the tube method but failed to react with the whole blood test, and on necropsy *S. pullorum* was recovered from the pericardium, liver, spleen, peritoneum, ovary and abdominal cyst. The serum of bird 95824 gave complete agglutination on initial test with the tube method, but subsequent tests were either negative or slightly suspicious. This bird did not react to the whole blood test and *S. pullorum* was not isolated. The observations concerning bird 95842 are of interest in that its titre gradually decreased below the 1:10 dilution and on necropsy *S. pullorum* was recovered from pericardial exudate. It is quite possible that complete recovery from infection might have followed since the organism appeared to be confined to the pathological process of the heart. Low-titre birds were either negative or gave inconsistent positive reactions with the whole blood test. On the initial test of the flock the tube test detected 19 reactors which were negative to the whole blood method. On second test 15 of these reactors (three submitted to the laboratory and one died) were tested and three continued to react. One also reacted to the whole blood test.

Flock D. This flock had not revealed pullorum-disease reactors for a period of 8 consecutive years. It was selected as a negative flock to determine the accuracy of the whole blood test as compared with the tube test in ascertaining the true status of the birds. The technique for the testing methods was the same as that employed in the first test of Flock A. A total of 906 birds was tested. Sixteen birds gave reactions that were slightly suspicious. Two of these reactions were delayed. With the tube test the sera of three birds gave a slightly suspicious reaction. None of the reacting birds were requested for necropsy since the degree of reaction observed with either test and the history of the flock did not suggest the presence of pullorum infection.

TABLE 11.--FURTHER OBSERVATIONS ON THIRTEEN REACTORS IN FLOCK C.

Bird No.	Date Detected	Routine Tube Test 1:25	Date of Test	Tube Test Dilution 10	20	40	80	160	320	640	1280	Whole Blood Test	Date of Necropsy	*S. pullorum* Isolated
92817	10/25/34	0	10/25/34	NT								1*	12/29/34	Negative
			11/7/34	0	0	0	0	0	0	0	0	0		
			11/10/34	1	1	0	0	0	0	0	0	0		
			11/15/34	1	1	1	1	0	0	0	0	0		
			11/20/34	1	0	0	0	0	0	0	0	0		
			11/30/34	4	2	1	0	0	0	0	0	0		
			12/13/34	2	1	0	0	0	0	0	0	0		
			12/19/34	3	1	0	0	0	0	0	0	0		
			12/26/34	3	1	1	0	0	0	0	0	0		
92836	10/25/34	3	10/25/34	NT	2	2	2	1	0	0	0	2	2/22/35	Negative
			11/7/34	2	1	1	1	0	0	0	0	0		
			11/10/34	2	1	1	1	0	0	0	0	0		
			11/15/34	2	2	2	1	0	0	0	0	0		
			11/20/34	2	1	1	0	0	0	0	0	1		
			11/30/34	2	1	1	0	0	0	0	0	0		
			12/13/34	2	2	1	1	0	0	0	0	0		
			12/19/34	2	2	1	1	0	0	0	0	1		
			12/26/34	3	2	2	1	0	0	0	0	0		
			12/31/34	0	0	0	0	0	0	0	0	0		
			1/8/35	2	1	1	1	0	0	0	0	0		
			1/16/35	2	2	2	1	1	0	0	0	1		
			1/23/35	2	1	1	1	0	0	0	0	0		
			1/31/35	2	2	2	1	0	0	0	0	0		
			2/5/35	3	2	2	2	1	0	0	0	0		
			2/15/35	2	2	2	1	0	0	0	0	0		
			2/30/35	1	1	1	0	0	0	0	0	0		
92842	10/25/34	0	10/25/34	NT								1*	2/22/35	Negative
			11/7/34	0	0	0	0	0	0	0	0	1		
			11/10/34	0	0	0	0	0	0	0	0	0		
			11/15/34	0	0	0	0	0	0	0	0	0		
			11/20/34	0	0	0	0	0	0	0	0	0		
			11/30/34	0	0	0	0	0	0	0	0	0		
			12/13/34	0	0	0	0	0	0	0	0	0		
			12/19/34	0	0	0	0	0	0	0	0	0		
			12/26/34	0	0	0	0	0	0	0	0	0		
			12/31/34	U	U	U	U	U	U	U	U	0		
			1/8/35	1	0	0	0	0	0	0	0	0		
			1/16/35	0	0	0	0	0	0	0	0	0		
			1/23/35	1	0	0	0	0	0	0	0	0		
			1/31/35	1	0	0	0	0	0	0	0	0		
			2/5/35	1	1	1	0	0	0	0	0	0		
			2/15/35	0	0	0	0	0	0	0	0	0		
			2/20/35	0	0	0	0	0	0	0	0	0		
92898	10/25/34	3	10/25/34	3	3	2	1	0	0	0	0	0	12/27/34	Negative
			11/7/34	2	1	0	0	0	0	0	0	0		
			11/10/34	1	0	0	0	0	0	0	0	0		
			11/15/34	2	1	1	1	0	0	0	0	0		
			11/20/34	1	1	1	0	0	0	0	0	0		
			11/30/34	2	1	1	0	0	0	0	0	0		
			12/13/34	2	1	1	0	0	0	0	0	0		
			12/19/34	2	2	1	0	0	0	0	0	0		
			12/26/34	2	1	1	0	0	0	0	0	0		
95824	10/25/34	4	10/25/34	NT								0	2/22/35	Negative
			11/7/34	0	0	0	0	0	0	0	0	0		
			11/10/34	0	0	0	0	0	0	0	0	0		
			11/15/34	0	0	0	0	0	0	0	0	0		
			11/20/34	0	0	0	0	0	0	0	0	0		
			11/30/34	0	0	0	0	0	0	0	0	0		
			12/13/34	0	0	0	0	0	0	0	0	0		
			12/19/34	1	0	0	0	0	0	0	0	0		
			12/26/34	0	0	0	0	0	0	0	0	0		
			12/31/34	0	0	0	0	0	0	0	0	0		
			1/8/35	0	0	0	0	0	0	0	0	0		
			1/16/35	0	0	0	0	0	0	0	0	0		
			1/23/35	0	0	0	0	0	0	0	0	0		
			1/31/35	2	1	0	0	0	0	0	0	0		
			2/5/35	1	0	0	0	0	0	0	0	0		
			2/15/35	1	1	0	0	0	0	0	0	0		
			2/20/35	0	0	0	0	0	0	0	0	0		
95825	11/28/34	2	11/28/34	NT								0	12/36/34	Negative
			12/19/34	4	4	2	0	0	0	0	0	0		
			12/26/34	4	3	1	0	0	0	0	0	0		

TABLE 11.--CONTINUED.

Bird No.	Date Detected	Routine Tube Test 1:25	Date of Test	Tube Test								Whole Blood Test	Date of Necropsy	*S. pullorum* Isolated
				Dilution 10	20	40	80	160	320	640	1280			
95829	11/28/34	2	11/28/34	NT								0	12/31/34	Negative
			12/19/34	2	1	0	0	0	0	0	0	0		
			12/26/34	1	1	1	0	0	0	0	0	0		
			12/31/34	3	2	1	0	0	0	0	0	1		
95833	10/25/34	U	10/25/34	U	U	U	U	U	U	U	U	4	12/26/34	Positive
			11/7/34	4	4	4	4	4	3	1	0	4		
			11/10/34	4	4	4	4	2	1	0	0	4		
			11/15/34	4	4	4	4	2	0	0	0	3		
			11/20/34	4	4	4	4	4	2	0	0	4		
			11/30/34	4	4	4	4	4	2	0	0	4		
			12/13/34	4	4	4	4	4	2	1	0	4		
			12/19/34	4	4	4	4	4	2	1	0	4		
			12/26/34	4	4	4	4	4	3	1	0	4		
95842	10/25/34	3	10/25/34	NT	3	2	1	0	0	0	0	1*	2/22/35	Positive
			11/7/34	4	4	3	2	0	0	0	0	2		
			11/10/34	4	4	2	1	0	0	0	0	1		
			11/15/34	4	3	1	0	0	0	0	0	0		
			11/20/34	4	4	2	1	0	0	0	0	0		
			11/30/34	3	1	0	0	0	0	0	0	0		
			12/13/34	2	1	1	0	0	0	0	0	0		
			12/19/34	2	1	0	0	0	0	0	0	1		
			12/26/34	2	1	0	0	0	0	0	0	0		
			12/31/34	3	1	0	0	0	0	0	0	0		
			1/8/35	3	2	0	0	0	0	0	0	0		
			1/16/35	2	0	0	0	0	0	0	0	0		
			1/23/35	3	2	0	0	0	0	0	0	0		
			1/31/35	1	0	0	0	0	0	0	0	0		
			2/5/35	0	0	0	0	0	0	0	0	0		
			2/15/35	2	0	0	0	0	0	0	0	0		
			2/20/35	0	0	0	0	0	0	0	0	0		
95928	10/25/34	4	10/25/34	NT	4	3	2	0	0	0	0	1*	12/29/34	Positive
			11/7/34	4	4	2	1	0	0	0	0	0		
			11/10/34	4	2	1	0	0	0	0	0	2		
			11/15/34	4	3	2	1	0	0	0	0	1		
			11/20/34	4	4	3	1	0	0	0	0	2		
			11/30/34	4	4	4	4	1	0	0	0	4		
			12/13/34	4	4	4	4	1	0	0	0	4		
			12/19/34	4	4	4	2	1	0	0	0	4		
			12/26/34	4	4	4	2	0	0	0	0	3		
95982	10/25/34	4	10/25/34	3	3	2	1	0	0	0	0	3	12/29/34	Positive
			11/7/34	4	4	3	1	0	0	0	0	2		
			11/10/34	4	3	2	0	0	0	0	0	4		
			11/15/34	4	3	2	1	0	0	0	0	2		
			11/20/34	4	4	3	2	1	0	0	0	2		
			11/30/34	4	4	4	3	1	0	0	0	4		
			12/13/34	4	4	4	4	2	1	0	0	4		
			12/19/34	4	4	4	4	4	2	0	0	4		
			12/26/34	4	4	4	4	3	2	1	0	4		
96027	11/28/34	2	11/28/34	NT								0	12/31/34	Positive
			12/19/34	4	2	1	0	0	0	0	0	0		
			12/26/34	1	1	0	0	0	0	0	0	0		
			12/31/34	4	3	1	0	0	0	0	0	0		
96031	10/25/34	3	10/25/34	NT								0	2/22/35	Negative
			11/7/34	4	2	1	0	0	0	0	0	0		
			11/10/34	2	1	0	0	0	0	0	0	0		
			11/15/34	4	3	1	0	0	0	0	0	0		
			11/20/34	3	2	2	1	0	0	0	0	0		
			11/30/34	4	4	4	1	0	0	0	0	0		
			12/13/34	4	3	2	1	0	0	0	0	0		
			12/19/34	2	2	1	0	0	0	0	0	0		
			12/26/34	2	1	1	0	0	0	0	0	0		
			12/31/34	4	3	2	0	0	0	0	0	0		
			1/8/35	3	2	1	0	0	0	0	0	0		
			1/16/35	3	2	1	0	0	0	0	0	0		
			1/23/35	4	4	2	1	0	0	0	0	0		
			1/31/35	4	3	2	0	0	0	0	0	0		
			2/5/35	4	3	1	0	0	0	0	0	0		
			2/15/35	4	3	2	0	0	0	0	0	0		
			2/20/35	4	3	1	0	0	0	0	0	0		

*Delayed reaction
U—unsatisfactory test
NT—not_tested

Discussion

From results obtained in this investigation, the whole blood test, as a diagnostic means of detecting infected pullorum-disease carriers, does not appear to be so efficient as the standard tube method. Antigen and whole blood measurements demonstrated that the quantities of antigen and of whole blood might vary considerably, and that the whole blood–antigen dilution was by no means constant. This variation in the whole blood–antigen dilution had a perceptible influence on the degree of agglutination and was especially significant in birds that possessed a low agglutination titre. Failure of such birds to react might be due to the whole blood–antigen dilution being beyond the agglutination titre. While a definite amount of blood appeared essential to obtain a reaction, yet a greater amount of blood did not seem to increase the intensity and rapidity of the agglutination. Equal amounts of blood and antigen appeared to give the best results, while amounts of blood greater than that of antigen seemed to form a colored mixture in which the clumping was observed with difficulty.

The whole blood and antigen dilution does not appear to be the only factor which influences the accuracy of the whole blood method. While the exact influence which uniform and constant incubation temperature exerted on the agglutination reaction was not definitely determined, it was observed that a controlled heating device was necessary to avoid extremes in temperature which would lead to an unsatisfactory test. The temperature range in which agglutination is not hindered can only be determined when other steps in the test are kept uniform and constant.

An adequate source of light is essential for accurate interpretation of the agglutination reactions. With a suitable light the clumping will appear distinctly and plainly visible, even when the clumps are few in number and small in size. With insufficient light the weak reactions may be completely overlooked.

Interference with the tests due to foreign material, such as dust particles and feathers, can be largely overcome by using a covered test plate. The glass test plate marked off in one-inch squares with a diamond pencil prevents the whole blood-antigen tests from spreading and running together. Rotating the test plate appears to hasten the clumping of the cells as well as to bring about a grouping of the clumps. The latter is especially true in strong reactions.

To what extent humidity, air currents, and other environmental factors influence the agglutination reaction remains a question. The fact that there has been no satisfactory investigation of the influence which any of the apparently important factors exert upon the agglutination reaction, makes it impossible to ascribe to the different factors their full significance in the whole blood agglutination phenomena.

Since it is impossible to produce on the poultry farm conditions which simulate those in the laboratory, it appears reasonable that the quality of the test conducted in the field would not be equal to that conducted in the laboratory. The rate of speed at which the testing is conducted appears to have a marked influence. Some persons are prone to sacrifice accuracy for speed. Such a service may be satisfactory to certain flock owners, but in an eradication program success is based upon accurate and reliable testing results. Sufficient time should be taken to measure the blood and antigen as accurately as possible, to mix them thoroughly and to incubate them for a satisfactory period. The length of the incubation period considered necessary for agglutination to occur varies with different investigators.

Lubbehusen and Beach have observed that agglutination may occur after a period of 10 to 12 minutes. While the majority of positive reactions occur within a very short time, yet some birds give delayed reactions which may be overlooked. These delayed reactions consist of fine clumps, few in number, which are in most cases impossible to distinguish from reactions obtained with birds that are non-specific reactors. As to what factors have a direct or indirect influence on the incubation period, our knowledge appears to be very limited. It is apparent, however, that blood from high-titred birds as a rule produces immediate agglutination. By perfecting the whole blood–antigen dilution and improving the sensitivity of the antigen, we may possibly anticipate encouraging results in the detection of the delayed reactors.

The adoption of the whole blood test as the sole diagnostic means for accrediting flocks free from pullorum disease would seem an inexpedient procedure at this time in certain sections of this country where considerable progress has been made in the establishment of pullorum-clean flocks. In those sections where flock owners have adopted and attained eradication as their goal, the livability of the chicks is not the only benefit derived from a pullorum-disease-clean flock; but the owners are relieved of the frequent retesting that is necessary in a flock from which infection is not completely eliminated. In certain sections where the whole blood test is employed extensively, the benefit claimed from it, and justly so, is the reduced chick mortality. However, that does not mean that pullorum infection is not present in those flocks, because occasionally infected pullets are detected by the tube agglutination test when there has been no previous suspicion of the disease. With the presence of any infection in a breeding flock, little control can be exercised over the amount transmitted to the progeny. The amount of infection passed on to the progeny is influenced by factors such as the number of infected eggs which hatch, effective incubator disinfection, proper care and handling of baby chicks, the virulence of the organism, and the natural resistance of the chicks. One or two infected birds in a breeding flock may be responsible for acute outbreaks of pullorum disease in the progeny.

Since the whole blood test has several desirable features, a concerted effort should be made to improve its diagnostic efficiency, followed by standardization of the different steps in the procedure of the test.

SUMMARY

The whole blood agglutination test was not as efficient as the standard tube agglutination method. Factors such as proper and constant temperature, adequate light, and an effective and constant whole blood–antigen dilution influence the sensitivity and efficiency of the whole blood agglutination test.

Great variation was observed in the whole blood–antigen dilution. The lack of constancy in this dilution exerted a perceptible influence on the degree of agglutination and played an important role in detecting low-titre birds.

Delayed weak reactions occurred in a few instances with blood obtained from birds that harbored *S. pullorum.* The standard tube test detected infected birds which failed to react with the whole blood test.

The adoption of the whole blood test as the sole diagnostic means for establishing and identifying pullorum-disease-free flocks seems inexpedient at the present time.

LITERATURE CITED

1. Barger, E. H., and Torrey, J. P. 1933. The whole-blood, stained-antigen agglutination test for pullorum disease. Jour. Amer. Vet. Med. Assoc. 82 (N. S. 35): 84-95.
2. Coburn, D. R., and Stafseth, H. J. 1931. A field test for pullorum disease. Jour. Amer. Vet. Med. Assoc. 79 (N. S. 32):241-243.
3. Durant, A. J. 1932. A comparison of three methods of testing for pullorum disease with finer interpretations of readings on the old tube agglutination test. Jour. Amer. Vet. Med. Assoc. 81 (N. S. 34):37-45.
4. Graham, R., Thorp, F., Jr., and Torrey, J. P. 1933. A study of pullorum disease diagnostic tests. Poultry Sci. 12:112-119.
5. Higgins, W. A., and Schroeder, C. H. 1934. The diagnostic value of the various tests for pullorum disease. Poultry Sci. 13:239-241.
6. Lubbehusen, R. E., and Beach, J. R. 1935. The place of the whole blood test in a pullorum disease eradication program. Jour. Amer. Vet. Med. Assoc. 86 (N. S. 39):620-634.
7. Schaffer, J. M., MacDonald, A. D., Hall, W. J., and Bunyea, H. 1931. A stained antigen for the rapid whole blood test for pullorum disease. Jour. Amer. Vet. Med. Assoc. 79 (N. S. 32):236-240.
8. Torrey, J. P., and Graham, R. 1934. Partial or doubtful reactors to the whole blood stained antigen for pullorum disease. Cornell Vet. 24: 156-162.
9. Van Roekel, H., Bullis, K. L., Flint, O. S., and Clarke, M. K. 1932. Twelfth annual report on eradication of pullorum disease in Massachusetts. Mass. Agr. Expt. Sta. Bul. 63.
10. Welch, H. 1932. A modification of the rapid agglutination test for pullorum disease. Jour. Amer. Vet. Med. Assoc. 80 (N. S. 33):778-781.
11. 1933. Report of the Conference of Official Research Workers in Animal Diseases of North America on Standard Methods of Diagnosis for Pullorum Disease in Barnyard Fowl. Jour. Amer. Vet. Med. Assoc. 82 (N. S. 35):487-491.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
3M-9-'35 No. 5616.

AGRICULTURAL BRANCH LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 324 August, 1935

Potash in Massachusetts Soils Its Availability for Crops

By F. W. Morse

VIRGINIA AGRICULTURAL EXPERIMENT STA

The proper use of commercial fertilizers is a factor in farm management based on related information from many sources. This bulletin brings together results from soil surveys, soil analyses, and general investigational work in Massachusetts with the aim of promoting the more efficient use of potassium as a plant-food element.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

POTASH IN MASSACHUSETTS SOILS: ITS AVAILABILITY FOR CROPS

By F. W. Morse, Research Professor of Chemistry

The Soil Survey Shows the Soils to be Derived from Potash Minerals

The soils of Massachusetts have been surveyed and classified by the Bureau of Soils of the United States Department of Agriculture; and the results have been published from time to time, as one area after another was covered. The survey of Plymouth County was made by W. B. McLendon and G. B. Jones, and was the first to be published. The other counties were all surveyed by W. J. Latimer, who was assisted by men supplied by the State Department of Agriculture. The publications of Mr. Latimer's survey began with Norfolk, Bristol, and Barnstable Counties, issued in one bulletin, and ended with Franklin County. His continuous service gave consistency to the classification of soils into series.

The system of classification is described in Soil Survey of Norfolk, Bristol, and Barnstable Counties (p. 1058):

> Soils can be divided into three main groups. Those of the uplands, where the material has been accumulated by the action of ice, and consists of a heterogeneous mixture of rock flour, sand, gravel, and stones, form one group. Another group includes the old stratified deposits usually lying at lower levels in the form of plains and in areas of more irregular topography. A third group comprises the areas of recent alluvium along the streams, where the process of accumulation is still going on.

In each of these major groups are minor groups, or what are called series. A series includes soils with a common origin, which are similar in color of surface, color and texture of subsoil, absence or presence of lime carbonate, and the depth to the substratum and its character. Each series is further subdivided into soil types which differ only in texture and are classified as loam, sandy loam, loamy sand, and many other types.

Since Massachusetts was completely subjected to the action of ice in the glacial period, its soils have been formed from the drift left by it. In the Soil Survey of Essex County (p. 12) Latimer says:

> In most places the glacial material from which the soils are derived, . . . is made up of material of the same mineralogical composition as the underlying rock. However, the ice movement from northwest to southeast across the area did, to some extent, drag material from its source onto the rocks to the south and southeast, but much of the material shows evidence that it has not been transported very far.

Since the glacial drift links the soil on its surface with the rocks beneath it, the minerals composing the soil must be similar to those in the rocks, although modified by weathering and plant growth.

Granite and gneiss are the rocks most widely distributed throughout the State. Both are made up of quartz, feldspar, and mica. Gneiss is finer grained than granite and splits readily into thin blocks. Mica schist is also a widely distributed rock. It contains more mica than granite and gneiss and splits into thinner sheets than gneiss. Slate and phyllite resemble schist in cleavage but are not as soft and are less common. Sandstone is common in the Connecticut Valley, and a coarser rock called pudding-stone is noticeable in Norfolk and Bristol Counties. They are classed together as conglomerate and contain a larger proportion of quartz than is found in granites and schists.

Limestone is a negligible rock east of the Connecticut River, although a small deposit in Bolton, on the eastern edge of Worcester County, supplied the needs of surrounding towns a century ago. The limestone formation of the Green Mountains extends into Berkshire and Franklin Counties and influences some of the soil within their bounds. The absence of limestone results in supplies of soft water for home and public use throughout most of the State. Reports of the State Board of Health show that streams supplying the Wachusett Reservoir carry water with a hardness of only 1, while mountain streams supplying Pittsfield bear water with a hardness of 5.3. But in those parts of Berkshire County where limestone is absent, the natural waters are as soft as those in the eastern counties.

In the Soil Survey of Worcester County, Latimer points out that weathering of the glacial drift seldom goes deeper than 4 feet and in most cases does not go beyond 30 to 36 inches. An accumulation of organic matter and a brown color are about the only changes from the underlying drift to the overlying soil (p. 1549). Corroborative of these observations by Latimer are the results of a survey of the area now submerged in the Wachusett Reservoir. This survey was made by the State Board of Health to determine the probable depth to which the soil must be removed from the bed of the reservoir, in order to prevent excessive organic matter in the water. Organic carbon was determined in numerous samples and at a depth of 36 inches was found to have shrunk to little more than traces in most cases and not more than .25 percent in any.

Granite and gneiss influence the largest area of soils of the State: 2,400,000 acres are included in the different series derived from such glacial material. The largest of these is called the Gloucester Series, and is found on the uplands. The drift from which it has been weathered was deposited directly by the ice as it ground its way across the land, and is a mass of earth ranging from clay to angular pieces of granite.

In the Soil Survey of Franklin County (p. 15), Latimer says:

> The soils of the eastern uplands, like most of the soils of eastern New England, are not inherently poor as is usually considered. Although they are not so fertile as the soils of the western plains or prairie regions of the United States, they are more fertile than most of the soils of the Atlantic Coastal Plain or Piedmont Region and compare favorably in fertility with the non-lime soils of the North Atlantic States.

The next series of granitic soils in extent is the Merrimac Series, which is derived from the glacial material deposited by the waters formed from the melting ice. The underlying drift is usually stratified and ranges from clay to rounded boulders worn by the water. These soils are found on the plains and terraces and gravelly knolls. In the Soil Survey of Hampden and Hampshire Counties (p. 18), Latimer says:

> The soils developed on the terraces are similar to the soils of southern New England in the same situations, and they approach in development and character the soils of the Atlantic Coastal Plain of Long Island and New Jersey . . . . However, they are less fertile than the hill or bottom-land soils, as they are weathered from lighter textured material than the hill soils and are leached to a greater extent than the upland or bottom-land soils.

Soils influenced by mica schist are also widely distributed and are divided into numerous series because the different schistose rocks vary in proportions of mica and in color. The most striking schist soils are those of the Brookfield Series in the central part of Worcester County. The Brimfield schist, which contains considerable iron, dominates the glacial drift and imparts a distinctive ellow color to these soils.

Soils derived from coarse conglomerate or pudding-stone are found principally in Norfolk and Bristol Counties where they are classed in the Coloma Series. Sandstone soils are limited to the Connecticut Valley, where Chicopee Soils on the plains and Cheshire Soils on the uplands include most of the acreage on such glacial drift.

Limestone influences about 240,000 acres of soil, of which 45,000 acres are in Franklin County and the major amount in Berkshire County. The Dover Series is derived from limestone drift. Several other series are formed from gneissic or schistose drift in which more or less limestone was intermingled by glacial action.

The chemical composition of the weathered soil is similar to that of the underlying drift, which in turn must be related to the rocks from which the drift was formed. These crystalline minerals, quartz, feldspar, and mica, make up much of the granite, gneiss, schist, slate, and sandstone of the glacial debris. Orthoclase feldspar and muscovite mica are both potash minerals. Dana states that the former contains 16 percent and the latter 9 percent of potash. Quartz does not contain potash.

While each crystalline mineral has its characteristic composition, rocks like granite from different localities differ in the proportion of each kind of crystals and may vary in the percentages of potash to be found. Feldspar is the dominant mineral in granite, while mica is most prominent in gneiss, schist and slate. Leith and Mead, in "Metamorphic Geology," state that granite contains an average of 4.1 percent of potash. The micaceous rocks average less. Quartz prevails in sandstones, but the coarse pebbles are usually of granitic character and sandstones are not barren of potash. Limestone is usually associated with other rocks like schist or gneiss. Although it does not contain potash, the weathering of limestone in glacial drift dissolves the limestone faster than it does the harder rocks which contain potash.

Effects of Potash in Fertilizer Experiments

Fertilizer experiments at the Massachusetts Agricultural College were begun soon after it was founded. From these experiments together with observations of farm practice, Stockbridge in 1876 published several formulas for fertilizers based on the chemical composition of the crops and their probable yields per acre. For example, a crop of 50 bushels per acre of corn might contain 64 pounds of nitrogen, 31 pounds of phosphoric acid, and 77 pounds of potash. To replace this fertility, the corn formula called for 320 pounds sulfate of ammonia, 248 pounds superphosphate, and 154 pounds muriate of potash.

Stockbridge's formulas were vigorously criticized by Director Johnson of the Connecticut Agricultural Experiment Station as uneconomical and therefore not practical. The large proportion of nitrogen was found to be uneconomical and was lessened without any reduction in effects. Goessmann's experiments, begun in 1883, finally settled in 1889 to the following quantities per acre: 45 pounds of nitrogen, 80 pounds of available phosphoric acid and 125 pounds of potash. By this time it had become generally known that nitrogen from the air was being fixed by bacteria which grew on roots of leguminous plants.

Soon after the establishment of the Office of Experiment Stations under the Hatch Act in 1888, its director, Dr. W. O. Atwater, suggested to the agricultural experiment stations of the separate states that fertilizer experiments should be conducted on different farms in order to show farmers what their soils most needed of the various kinds of fertilizers. He called a conference of experiment station representatives to formulate a plan of uniform fertilizer experiments, at which it was settled that the fertilizers to be employed should consist of 160 pounds nitrate of soda (16 percent nitrogen), 320 pounds dissolved boneblack (16 percent soluble phosphoric acid), and 160 pounds muriate of potash (50 percent actual potash) per acre. When all three substances were applied together, the soil would receive per acre 25.6 pounds nitrogen, valued at $4.35; 51.2 pounds soluble phosphoric acid, valued at $4.10; and 80 pounds potash, valued at $3.60. The outstanding features of this combination of fertilizer chemicals were the simple units of 1 and 2 pounds per square rod, and the nearly equal distribution of cost between the three kinds of fertilizers used.

The plan of cooperative fertilizer experiments was adopted by this station and was executed by Dr. Wm. P. Brooks. Cooperation of farmers was secured in thirteen different towns, distributed from Cape Cod to the Berkshire Hills. Most of the experiments were conducted in 1889, 1890, and 1891; three were continued until the seventh annual crop was secured. Nearly all the fields selected for the experiment were fairly level and free from stones, and had been several years in grass, either as hayfield or pasture, without manure or fertilizer of any kind.

All the experiments used corn for the first crop. On some farms, new fields were used in the succeeding years, but in most cases the same fields served year after year. Potatoes or oats were used for succeeding crops on a few farms. Most of the experiments showed that the fields required all three forms of fertilizer for the highest yields. One hill farm in Shelburne did not require potash, and one near the river in Montague needed only nitrogen at that time. A comparison of localities and description of soils with the soil surveys shows that these cooperative experiments were almost always on the soils of the plain and terrace group. The Shelburne soil was in the upland group, and the Montague soil may have belonged to the alluvial or river-bottom group. All fertilizer experiments at this experiment station have been on soils of the plain and terrace group.

The results of these numerous fertilizer experiments with a variety of crops, together with the relatively low cost of potash fertilizers, led to recommendations for liberal applications of potash to most crops on all soils in this State.

At the New Hampshire Agricultural Experiment Station, however, fertilizer experiments on its soils and observation of farm practices in its vicinity showed that the liberal use of potash was unnecessary on such soils. In general, they were a clay loam overlying a dense unweathered clay, or granite rock. Angular boulders of granite were scattered through the soil and showed that the material had been deposited from the melting glaciers as they approached the ocean, and not from streams of water. In fertilizer experiments with grass and clover, potash gave no increases in yields, while nitrogen alone produced marked gains. Analyses of the crops showed that the percentages of potash in the crops were fully maintained by the soil. Such results indicated that liberal applications of potash might be uneconomical because a part of the crop's needs could be obtained from the soil without its impoverishment.

Review of Soil Analyses

In the Annual Report of the Massachusetts Agricultural Experiment Station issued in 1911, there are descriptions and chemical analyses of thirteen soils which represent distinctive geological formations in different sections of the State (pp. 339-341).

In 1914 Director Wm. P. Brooks had these typical localities again sampled, together with some additional areas. The purpose of this later study was to determine whether the subsoils were richer in potash than the surface soils. Localities were chosen because of typical underlying rock or glacial drift. The areas selected for the sampling were in uncultivated pastures or woodland. Samples were secured of the surface soil 6 to 8 inches in depth and each foot of subsoil to the sixth foot in depth. The field work was done by Robert L. Coffin. The chemical analyses were made of the fine soil which passed through a sieve with holes 1 millimeter in diameter and were limited to the loss on heating the soil to red heat and to the potash soluble in hydrochloric acid solution of specific gravity 1.12. All the chemical analyses were made by Walter S. Frost. The results have remained unpublished until now.

Since these soil samples were secured, the soil surveys have been published and by the soil maps the soil series for each of the localities has been identified and included in the table with the analytical data. The three major groups of soils are each represented by these samples: Glacial drift, water-borne drift, and recent alluvial soils. The analytical data in the table are not carried beyond the 4th foot in depth.

TABLE 1.--POTASH IN MASSACHUSETTS SOILS

Soil Group	Soil Series	Locality	Percentage of Potash				
			Surface Soil	Subsoil			
			6-8 in.	1 ft.	2 ft.	3 ft.	4 ft.
Glacial Drift							
Granite	Gloucester	Dedham	.20	.14	.20	.35	...
Gneiss	Gloucester	Wendell	.15	.15	.17	.14	.27
Mica Schist	Hollis	Deerfield	.29	.43	.53	.52	.53
Pyrites Schist	Brookfield	Templeton	.10	.10	.06	.07	.23
Sandstone	Cheshire	Agawam	.14	.11	.15	.15	.14
Limestone	Dover	Pittsfield	.18	.13	.07	.09	.20
Water-borne Drift							
Plain	Merrimac	Concord	.18	.12	.15	.16	.17
Plain	Merrimac	Marshfield	.08	.07	.09	.05	.06
Terrace	Hadley	Hadley	.29	.24	.24	.22	.14
Plain	Chicopee	Agawam	.19	.20	.14	.19	.20
Lowland	Scarboro	State College	.43	.33	.28	.24	.27
Recent Alluvial Soils							
Fresh-water Meadow		East Sudbury	.21	.27	.55	.64	...
Diked Tidal-marsh		Marshfield	.72	.77	.86	.69	...
Cranberry Bog Peat		North Carver	.08	.10	.11	...	...

Aside from the marsh soils, the only soil showing marked increases in potash in the 1st and 2nd feet of subsoil is the Hollis soil from Deerfield. This soil series is derived from a slaty schist high in mica, which is the principal potash mineral in such rocks. The variation in potash may be due to leaching, but is more probably due to different proportions of mica when the several levels were deposited.

In the Survey of Worcester County Soils (pp. 1544-1547), Latimer discussed the formation of soils from glacial drift, bringing out these salient points. Soil-forming processes have not yet effected any profound changes in the soil material. One of these processes removes clay from the surface layer, carries it downward, and deposits it in the layer beneath. The surface layer becomes coarser in texture, while the underlying layer becomes finer. Six Worcester County soils of different series showed no marked increase in clay at depths between 6 inches and 2 feet. They are young soils because the changes which have taken place in the glacial material are comparatively slight.

Soils are never wholly dissolved in the solution of hydrochloric acid used in these analyses. The proportion that is dissolved depends principally upon the fineness of the soil particles. Clay will dissolve more freely than the finest sand. In glacial soils, the clay was formed by the grinding action of the moving ice, which reduced the softer minerals to rock flour. Feldspar, which contains potash, is softer than quartz, which does not contain any. The finer the soil, the more potash it may yield to any solution and clay may appear to be richer than sand.

Numerous samples of soils from different levels were procured from the vicinity of the College and analyzed by Frost, who also subjected them to a mechanical analysis by separation into several graded sizes of soil particles. In the next table are given the results of the mechanical analyses as well as the percentage of potash in those samples.

TABLE 2.--POTASH AND TEXTURE OF SOILS AT MASSACHUSETTS STATE COLLEGE

Locality	Soil Level	Potash Percent	Texture (Percent)			
			Clay	Silt	Very Fine Sand	Fine Sand
Campus Trench (North of cross-walk)...........	Surface	.24	1.8	56.3	26.3	6.8
	1st foot	.38	9.6	38.1	32.2	11.0
	2nd foot	.99	26.5	30.1	10.6	21.9
	3rd foot	1.22	22.1	36.3	21.5	7.4
	4th foot	1.18	35.8	24.4	20.8	10.4
Campus Trench (Southwest of Draper Hall)......	Surface	.66	7.7	23.5	24.1	7.3
	1st foot	.50	1.7	36.9	34.8	8.4
	2nd foot	.24	.6	19.9	47.7	13.2
	3rd foot	.88	7.3	33.5	12.4	7.2
	4th foot	1.29	19.7	36.3	18.5	3.2
Farm Pasture (Untilled many years)...........	Surface	.28	2.5	31.4	51.1	6.9
	1st foot	.18	.9	53.5	38.2	4.1
	2nd foot	.18	.9	46.8	42.5	6.8
	3rd foot	.13	.8	25.8	30.6	36.5
	4th foot	.20	.9	26.9	41.7	26.1
Farm Meadow (West of hay barns)............	Surface	.23	2.8	34.0	50.4	6.0
	1st foot	.27	1.5	17.1	48.1	24.3
	2nd foot	1.17	8.6	22.1	18.0	22.6
	3rd foot	1.73	20.0	11.8	21.7	5.5
Experiment Station (Forage crop plots).............	Surface	.14	.2	7.3	62.1	24.5
	1st foot	.11	.1	5.1	39.7	43.8
	2nd foot	.13	.3	7.1	46.5	27.6
	3rd foot	.06	.04	.1	.3	3.4
	4th foot	.09	.09	.3	.4	7.9

The soils represented by these samples show wide variations in texture when they are separated into the different grades of soil grains. High potash in the whole soil accompanies the larger proportions of clay, whether it be surface soil or the lowest levels. All of these soils were deposited from water coming from the melting glaciers. Excavations reveal very irregular distribution of clay, sand, and gravel; but the deposits represent long periods of alternate summers and winters, with the accompanying thawing and freezing, floods, and ice. The extremes in texture and potash are shown by the Campus Trench near Draper Hall and the Forage Crop Plots, yet they are less than 30 rods apart and practically in the same field.

The loss in weight which occurs when a dry soil is heated to red heat is commonly calculated to be organic matter; but this is not accurate because the clay does not part with all its water in the drying oven but does lose it at the higher heat. Lime carbonate also loses weight on heating to redness and is changed to quicklime. Frost's results on the soils in this investigation are of interest because in all cases except clay and limestone soils the loss at red heat was less than 1 percent in the samples from the 3rd and 4th foot, while in the surface soil it ran as high as 12 percent. Such results agree with those reported for organic carbon at the Wachusett Reservoir and confirm Latimer's statement about the depth of weathering of glacial drift from which the soils are formed.

During the existence of the experiment station many samples of soil have been analyzed, which have been sent from all parts of the State. In the Annual Report of January 1911 there were published detailed results on 148 samples. From these pages it was found that the potash dissolved in strong acid fell below .25 percent in 88 samples; was between .25 and .45 percent in 39 samples; and amounted to .45 percent and upward to 1.02 percent in 21 samples. Little can be learned from these results beyond the facts that many of the low results were from sandy and sandy loam soils, while several of the highest results were obtained from garden soils. Hilgard, in his book "Soils," makes the statement from long experience that soils with less than .25 percent of acid-soluble potash will need potash fertilizers, while those with .45 percent or more seldom show any benefit from such fertilizer. One fourth of the samples were between these two extreme groups and should require some thoughtful observation of results of fertilizers.

At the International Congress of Soil Science at Washington, D. C., in 1927, the consensus of opinion held the strong hydrochloric acid solution of soils to be an excellent index of the extent to which the soil minerals had been changed by weathering. The relation of the soil minerals to the underlying drift and rocks is better shown, however, by determining the total percentages by other methods such as fusion with some chemical.

In the soil surveys of Massachusetts only two chemical analyses of typical soils have been reported. These soils were Gloucester stony fine sandy loam and Becket loam, the complete analyses of which were published in the Soil Survey of Franklin County (p. 35). Both of these soils are derived from granite, gneiss, and related rocks. The deep subsoil of Becket series is compact and fine, while Gloucester soils are underlaid by looser and coarser material. In these analyses the soils were not dissolved in acid but changed to soluble compounds by fusion with alkalies in order to recover all the plant food. The data for total potash are given here.

	Depth Inches	*Total Potash Percent*
Gloucester stony fine sandy loam....	0—3	2.50
	3—5	2.33
	5—15	2.60
	15—24	2.64
	24—36	2.29
Becket loam......................	0—6	2.06
	6—11	2.89
	11—13	3.41
	13—24	3.45
	24—36	3.79

Bizzell has published complete analyses of a large number of New York soils in Bulletin 513 of the Cornell University Agricultural Experiment Station. Among them are several series common to Massachusetts: viz., Coloma, Dover, Dutchess, Gloucester, and Merrimac. All the determinations were for total and not acid-soluble constituents. Below are given summarized results for the five different series, limited to the potassium in the surface soil to a depth of 8 inches. Since the percentages are of potassium, the figures are somewhat smaller than if calculated for potash, which is potassium oxide.

TABLE 3.--TOTAL POTASSIUM IN SOME NEW YORK SOILS
(BIZZELL)

	Number of Samples	*Percentage of Total Potassium*		
		Maximum	*Minimum*	*Average*
Coloma fine sandy loam..	3	1.84	1.73	1.81
Dover loam.............	2	2.86	2.86	2.86
Dutchess silt loam.......	3	1.82	1.07	1.48
Gloucester loam.........	4	2.64	1.68	2.17
Merrimac sandy loam....	2	2.69	2.36	2.53

Morse and Curry published numerous determinations of total potash in clay loam and clay soils in the Report of the New Hampshire Agricultural Experiment Station for 1906-1908 (p. 265). In twelve lowland soils, total potash ranged from 2.21 to 3.96 percent; in ten upland soils, the range was from 2.05 to 2.75 percent.

Bizzell noted that clay loams and clays were much higher in potassium than the soils of lighter character. Sands were especially low in that substance.

Failyer, Smith, and Wade of the U. S. Bureau of Soils made a study of the plant-food constituents contained in the different sizes of soil particles separated into sands, silt, and clay. The study covered many representatives of numerous soil series and its results were published in Bulletin 54 of the Bureau. Of their examination of glacial soils, they say (p. 24), "In general, the finer separates of the soils of this group contain the greater percentages of the several elements determined . . . The glacial soils consist largely of crushed rocks. Much of the material composing them has not been profoundly weathered." Of the potash content, they say (p. 30), "the clays of the glacial soils contain about twice the percentage that the sands do." In the summary (p. 35) it is stated that as a general rule the smaller particles of soils are richer in potassium, calcium, magnesium, and phosphorus than the coarser particles. In glacial soils, the coarser particles are relatively high in percentage of potash, lime, and magnesia. The larger mechanical components contain these elements in forms which by protracted weathering will become more soluble, and they will ultimately be concentrated in the finer components. A comparison of soils with crystalline rocks indicates that, in the process of weathering, the lime and potash seem to decrease in percentage, although minerals containing them are always present.

Potash in Sand, Silt and Clay of Two Fields

In Bulletin 232 of this experiment station, Haskell showed that crops on Field G were much less influenced by potash fertilizers than crops on the North Soil Test.

The soils of the two fields were compared in pot experiments without additional potash but with varied supplies of water. The experiments have been reported in the *Journal of Agricultural Research*, Vol. 35 (1927). Japanese millet took up nearly twice as much potash from Field G soil as it could obtain from the soil of the North Soil Test, and on both soils it took up more potash with a liberal water supply than it did with a scanty supply.

The soils of Field G and the North Soil Test were next compared by both mechanical and chemical analysis. Samples were obtained from five plots on Field G and from eight plots on the North Soil Test, none of which had received any potash fertilizer. Each sample was a composite of several borings to the depth of 8 inches. A weighed portion of the dry sample was first sifted to remove the coarse sand. The fine soil was next separated into two groups of particles by repeated subsidence in water. In one group were the sand grains and in the other the silt and clay together with floating organic particles. For chemical analysis the sands of the plots of each field were blended into a composite sample for that field, and similarly with the silt clay particles. A portion of the sand sample was next pulverized to a fine powder in an agate mortar. Total potash was determined by fusion with calcium carbonate and ammonium chloride.

TABLE 4.--PERCENTAGES OF SAND, SILT-CLAY, AND POTASH IN THE SOIL OF TWO EXPERIMENT STATION FIELDS

Field G			North Soil Test		
Plot	Sand	Silt-Clay	Plot	Sand	Silt-Clay
1........	77.6	18.4	3E.......	86.3	11.1
9........	74.1	21.9	3W.......	88.5	9.5
17........	79.3	17.7	4E........	84.2	12.7
25........	77.4	20.0	4W.......	81.7	16.8
33........	73.4	22.9	6E........	88.2	8.6
			6W.......	85.3	11.7
			8E........	91.5	4.6
			8W.......	87.0	9.9
Average...	76.4	20.2	Average...	86.6	10.6
Potash....	1.90	2.57	Potash....	1.97	2.41

It may be noted that the soil of every plot on Field G contained more silt and clay than any plot on the North Soil Test, and the average for Field G soil shows twice as much silt and clay as in the other field. The percentages of potash in the two soils indicate them to be essentially alike in mineral composition. The silt and clay are definitely richer in potash than the sands, but in the soil as a whole the bulk of its potash is in the sands.

Excavations have shown that the two fields probably possess distinctly different underlying drift. The Forage Plots included in Frost's work are immediately adjacent to the North Soil Test and were positively coarser in their lower levels. On the other hand, a deep trench recently dug across the end of the original Field G showed heavy clay in those levels. Field G contained more potash in fine particles to be acted on by water, and also an underlying unweathered drift of great capacity to retain water. Hence a liberal supply of soil-potash was available.

Potash in Sand, Silt and Clay of Different Soil Series

Samples of soil representing different soil series have been analyzed with the object of comparing the percentages of total potash in the two groups of soil particles, sands and silt–clay. Some of the samples were from series of wide distribution. Others were from series with distinctive rocks predominating in the drift from which the soils were weathered. The samples were taken at locations which appeared to be distinctive of the particular series, shown by rock fragments, color of soil, and other characteristics. They were essentially random samples of Massachusetts soils, because there are numerous variables influencing the chemical composition of any particular soil series.

Glacial action has been stated by Latimer as reducing rocks to sand and rock flour. The softer minerals like feldspar would be more finely ground than the harder quartz. Therefore, the rock flour might contain more feldspar and the sand more quartz. Mica, which splits into thin, paper-like sheets, would slip and slide and instead of being pulverized to flour might remain as fine scales in the sands. Mica crystals contain 9 percent of potash, while potash feldspar contains 16 percent. Rock flour has been subjected to the dissolving effect of water throughout its formation and subsequent weathering, which must modify the percentage of potash originally present in the feldspar much more than the percentage of that element in the mica scales.

Among the different soils in the table, Brookfield, Cheshire, Dover, Gloucester, and Merrimac soils have been mentioned as influenced respectively by schist, sandstone, limestone, and granite in the glacial drift from which they have been weathered. The Gloucester and Merrimac soils are both granitic but differ in the form of the drift: the Gloucester drift was deposited directly from the ice as it melted, while the Merrimac drift was washed away in the streams of water from the melting ice and deposited at some distance. Becket soils were weathered from drift containing more gneiss than granite, which produced a finer grained, more compact drift than that underlying Gloucester soils. Becket soils are common on the hills west of the Connecticut River. Charlton soils form an important series in Worcester County and were weathered from drift containing both schist and granite, which is compact and retentive of moisture. Holyoke soils are limited to the vicinity of the Holyoke Mountain Range, and are of interest because the distinctive rock which characterizes them is trap rock or diabase, and diabase contains little if any potash. Lenox soils are underlaid by drift in which limestone and schist are mingled together. The sample was taken in the vicinity of a mica schist outcrop and its coarse sand contained numerous grains of limestone, which were identified by the action of weak acid on them.

Three samples of soils were taken near outcrops of ledges where the soil was not more than a foot in depth above the underlying rock. It is uncertain how much of the soil was weathered from the rock and how much from thin glacial drift. Diorite rocks are not mentioned by Latimer in connection with any series of soils. They are mentioned by Emerson in "Geology of Massachusetts" as fairly common in the ridges east of the Connecticut Valley. Diorite is of interest because, instead of potash feldspar, it contains lime and soda feldspar; therefore soils weathered from diorite may be poorer in potash than those derived from granite. Phyllite resembles slate in its composition, but does not cleave in thin sheets. It is distinctive in the Bernardston soils and is related in its properties to the slate of Hollis and Dutchess soils. Mica schist represents the dominant rocks underlying the glacial drift from which Berkshire soils have been weathered, and is unlike in color the iron-stained schist of the Brookfield Series.

TABLE 5.--PERCENTAGES OF SAND, SILT-CLAY, AND POTASH IN SOME MASSACHUSETTS SOIL SERIES

Soil Series	Locality	Sand	Silt-Clay	Potash	
				In Sand	In Silt-Clay
Surface Soils					
Becket	Windsor	75.4	12.2	2.87	2.31
Brookfield	North Brookfield	80.2	7.5	1.91	1.45
Charlton	Paxton	73.7	12.7	2.12	2.12
Cheshire	Amherst	75.2	15.1	1.40	2.17
Dover	Great Barrington	68.9	17.9	2.44	2.34
Gloucester	Hardwick	76.1	9.9	1.50	1.53
Holyoke	Mt. Tom	70.4	11.9	1.46	1.72
Lenox	Lenox	73.0	19.0	3.19	3.43
Merrimac	Amherst	76.4	20.2	1.90	2.57
Merrimac	Berlin	71.3	8.7	1.96	1.69
Average of Surface Soils		74.6	13.5	2.07	2.13
Soils near Ledges					
Diorite	Greenwich	74.2	13.9	1.27	1.53
Mica Schist	North Adams	77.2	16.4	3.91	3.18
Phyllite	Clinton	65.9	11.6	2.19	2.64
Subsoils					
Gloucester	Hardwick	74.3	12.0	1.57	1.66
Brookfield	North Brookfield	86.5	6.1	1.45	1.85

The mica schist soil showed more potash in the sand than in the silt-clay, which may be due to the accumulation of fine mica scales in the sand. The soil from the diorite outcrop was lowest in potash, indicating it to be weathered from the underlying rock. It is possible that the Gloucester soil from Hardwick was influenced by diorite because the glacial movement may have dragged material from the diorite localities onto the Hardwick ridge. A painstaking mineralogical analysis would be necessary to determine the facts.

The Holyoke soil indicates the mixing effect of glacial action because it contains a reasonable amount of potash, although diabase, its dominant rock, contains as a rule none. Becket and Brookfield soils have micaceous characteristics and have higher potash in the sands. The two Merrimac soils represent distinctly different formations of water-borne drift. The Amherst soil is an outwash formation, and is not stratified but is irregular in its make-up of clay, sand, and gravel. The Berlin soil represents the typical Merrimac stratification and was underlaid by coarse gravel, which permitted rapid percolation and drainage. The lower potash in the clay may be due to leaching. It may be noted that the percentages in the sands are closely alike in the two samples.

A majority of the samples have higher potash in the silt–clay particles. However, the averages for the ten surface soils show potash practically equal for the two groups of soil grains. Since sands constitute approximately 75 percent of the soils, however, it follows that the bulk of soil-potash is contained in them; and, as Failyer has remarked, it is a large reserve to be gradually weathered into availability for plants.

Soil Potash Soluble in Water

Potash in commercial fertilizers is required by law to be soluble in water. The amount of water-soluble potash in soils has received comparatively little study.

Morse and Curry found that, in the soils around the New Hampshire Agricultural Experiment Station, water-soluble potassium ranged from 6 to 18 parts per million parts of soil in upland soils, and from 6 to 35 parts in lowland soils. Fraps has reported water-soluble potassium in over 200 Texas soils, of which more than half contained between 6 and 36 parts per million parts of soil. The remainder of the soils extended the range as high as 168 parts. Shedd in *Soil Science* has described eleven Kentucky soils of silty and silty loam types. In eight of them, water-soluble potassium ranged between 14 and 30 parts per million parts of soil; one sample contained 97 parts. King, in Bulletin 26 of the Bureau of Soils, U. S. Department of Agriculture, has reported an exhaustive study of eight distinct soils in as many different parts of the nation. The water-soluble potassium naturally present in them ranged from 9 to 25 parts per million parts of soil.

From these different reports it may be calculated that in many soils there may be between 10 and 65 pounds of actual potash per acre in the surface 6 inches that is immediately soluble in water. Furthermore, there is evidence that as plants absorb the soluble potash, more of it passes into the soil solution from the soil grains.

King treated his soils eleven successive times with water, with a thorough drying of the sample between the treatments, and succeeded in recovering from 128 to 273 parts of potassium per million parts of the soils. Fraps conducted pot experiments with all of his soils in which he grew two successive crops without adding fertilizer. The crops were analyzed. The first crop contained more than three times as much potassium as was found in the water solution. Both crops together contained about six times the amount.

At this experiment station, in the different fertilizer experiments, plots without potash have borne crops that contained from 20 to 90 pounds of potash per acre. If these quantities were distributed in the surface 6 inches, there would be approximately 13 to 60 parts of potash per million parts of soil, which dissolved in the soil solution before being absorbed by the plants.

Morse and Curry reported sixteen soils in which water-soluble potassium was determined. The grass crops growing on these soils were also analyzed for potash. The soils were divided into two groups of eight soils each.

	Water-soluble Potassium in Soils Percent	*Potash in Crops Percent*
Group A.	6.0 to 13.8	.79 to 1.46
Group B.	15.8 to 35.1	.84 to 1.65

The crops from the soils with the higher water-soluble potassium had absorbed the larger percentages of potash.

The amount of water transpired by crops, together with the percentages of potash contained in them, may be used to show the solubility of potash in the soil.

Lyon and Bizzell, in Memoir 12 of Cornell University Agricultural Experiment Station, have reported data from which has been calculated the possible concentration of potash in the water when taken into the plant. Especially striking were their results for the seasons of 1913 and 1914, in two soil tanks, with hay from mixed grasses. The yields of hay and the potash contained in the crops were reported in pounds per acre. The transpiration ratio is the amount of water apparently taken up by the plant in producing a pound of hay. From this ratio was calculated the probable total water taken up by the crop and its concentration in potash. In 1914 the abundant rainfall allowed a liberal supply of water to the growing grass which enabled it to use potash more efficiently than in 1913 and in a more dilute solution. Similar results were obtained with timothy grass in four other soil tanks.

TABLE 6.--POTASH IN TRANSPIRED WATER OF HAY CROP, AT ITHACA, N. Y.

	1913	1914
Hay, pounds per acre	4,519	6,063
Potassium in crop, pounds	41.4	34.6
Transpiration ratio	266: 1	408: 1
Total water, pounds	1,202,000	2,473,000
Potassium in water, parts per million	34	14
Rainfall, April 1 to August 21, inches	10.15	20.72

Briggs and Shantz of the Bureau of Plant Industry made a comprehensive study of the water used by many different kinds of plants. They reported that the corn plant transpired 415 pounds of water as the maximum and 342 pounds as the minimum for each pound of dry matter built up in the plant. The plants were grown in soil contained in large pots, and water was supplied as liberally as needed by the crops, which varied with the season.

At this experiment station, numerous analyses of crops have shown approximately 1 percent of potash in the dry matter of corn crops. This amount of potash would be equivalent to 24 parts per million parts of water with the maximum transpiration and 29 parts with the minimum transpiration.

Availability of Soil Potash for Crops

Fertilizer experiments in the field, together with chemical analyses of crops in the laboratory, supply data from which may be estimated the availability of the potash naturally present in the soil.

Morse and Curry found that hay crops on heavy clay loams took from the soil from 60 to 90 pounds of potash per acre, when nitrogen and rainfall were in ample supply. Field G of this experiment station supplied hay crops with from 74 to 95 pounds of potash per acre. On the coarser sandy loams of North Soil Test and South Soil Test, hay crops were much influenced by variations in rainfall. In the favorable seasons, they were able to secure from 40 to 50 pounds of potash per acre.

Corn on Field G took up 45 to 65 pounds of potash per acre, but on the coarser soils it seldom got more than 25 pounds except when it followed hay crops, the turf of which yielded about twice as much potash. Our fertilizer experiments have shown that the coarser soils were somewhat exhausted of soluble potash after the turf was wholly used.

The investigations by Briggs and Shantz showed that clover transpired about twice as much water as corn in proportion to its weight, which would make it possible to get more potash into its tissues. Grasses were between corn and clover in the amount of water transpired.

Economical Use of Potash Fertilizers

The field and laboratory data often show that more potash is applied in fertilizers than the crops will take up.

Two soil tanks at the New York State Agricultural Experiment Station received, over a period of sixteen years, muriate of potash that was equivalent to 1184 pounds of potassium per acre. The crops took up the equivalent of 894.9 pounds of potassium and the drainage water carried away 77.5 pounds of potassium per acre. There remained in the soil 212 pounds of potassium, which was more than 17 percent of the amount applied.

Fixation of potassium in the soil by transformation of soluble potash salts into less soluble soil compounds has been much studied by investigators of soils. The opinion was general at the First International Congress of Soil Science that potassium thus fixed in the soil was later available for crops.

When soluble potash is abundant in the soil, crops may take up more than appears to be needed for growth. In our pot experiments it was found that soybeans grown in soil with residual potash weighted 393 grams and contained 4.8 grams of potash. On the same soil with a liberal addition of sulfate of potash, the pots produced 390 grams of crop which contained 8.5 grams of potash. Similar results were obtained with Japanese millet in other pots filled with the same soil. An excessive supply of fertilizer potash is not economical when taken up by the crop. The only short cycle of recovery of the potash in the crop, other than plowing the crop under, is to feed the crop to animals and return the potash in farm manure. Losses occur in such a cycle, some of which cannot be avoided.

Lyon and Bizzell in Memoir 134 of the Cornell University Agricultural Experiment Station described experiments with soil tanks in which, during fifteen years, 536 pounds of potash per acre had been applied in farm manure. During this period the drainage water had carried away 975 pounds of potash per acre. The decomposing manure apparently decomposed some of the mineral potash, as Vandercavey has shown with decomposing straw in investigations reported by him in *Soil Science.*

The application in fertilizer of all the potash that a crop can take up may be an extravagance. It is using the deposits of potash salts, which exist in limited areas, for wide distribution with the possibility of their ultimate exhaustion. The naturally available soil potash may require reenforcement, but its reasonable use may be considered as income from a substantial principal.

The fundamental differences between the soils which have appeared to need potash and the soils which have not needed it are differences in soil texture and in water supply. Light soils with their larger proportion of sand grains yield their potash sparingly to the soil water, which is also scanty unless rains are frequent. Heavy soils, with much more of clay and silt, hold more water in which the potash dissolves more freely from the fine soil particles.

Efficient use of fertilizer potash requires consideration of the soil texture and the water supply. Abundance of water will enable a crop to make use of soil potash. Scanty water supply should be supplemented with easily dissolved potash fertilizers.

Summary

The soils of Massachusetts have been completely surveyed by the U. S. Bureau of Soils, aided by the State Department of Agriculture. The soils are derived from glacial drift, which consists principally of material from potash-bearing rocks.

Fertilizer experiments have been limited almost wholly to soils of plain and terrace formation, which were more leached than upland soils or those of alluvial origin. The lighter soils required potash. Heavy clay soils did not respond to potash fertilizers.

Many analyses have been made at the experiment station of soil samples from all parts of the State. Potash has been determined in an acid solution. So far as can be ascertained, the percentages of potash have been influenced principally by the texture of the soil. The finer the soil, the more potash has been dissolved by the acid.

The soils of two fields used for fertilizer experiments have been sampled plot by plot where no potash fertilizer had been used. The samples were separated into sands and silt–clay. The sands contained a lower percentage of total potash by fusion than the silt–clay but held the major portion of the soil-potash. One soil contained twice as much silt–clay as the other, which indicated a larger amount of available potash.

Characteristic samples of important soil series were separated into sands and silt–clay. Total potash by fusion was determined in them. The average percentage of potash in sands was 2.07 and in silt–clay 2.13. The lowest percentage of potash was 1.27 in the sands overlying a diorite ledge.

A review of investigations of the water-soluble potash in soils showed that the soil particles yield an important part of the potash required by crops. Efficient use of potash fertilizer should include the available soil potash as part of the supply for the crop.

Clay presents more surface to the soil-solution than sand and also holds more water. Therefore, clay soils supply more available potash than sandy soils of similar origin.

Publication of this Document Approved by Commission on Administration and Finance
3M-9-'35. No. 5617

VIRGINIA POLYTECHNIC INSTITUTE
AGRICULTURAL [illegible] LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 325 October, 1935

VIRGINIA AGRICULTURAL EXPERIMENT STA.

Poultry Flock Improvement

By J. C. Graham

VIRGINIA AGRICULTURAL EXPERIMENT STA.

Many commercial poultrymen in the State are anxious to develop a high degree of efficiency in their flocks but hesitate to undertake pedigree breeding. This project was, therefore, planned to determine whether it is possible to build up and maintain desirable characters in a poultry flock without pedigreeing, but through the annual introduction of males from superior stock.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

POULTRY FLOCK IMPROVEMENT

By J. C. Graham, Professor of Poultry Husbandry

The purpose of this bulletin is to set forth the results to date of the Flock Improvement Project inaugurated in 1930, together with certain interpretations and conclusions. As it was necessary to carry on the work at a very moderate cost, the size of the project was limited. However, the number of birds involved was large enough to show definite trends.

This is termed a "flock improvement project" to distinguish it from pedigree breeding. In the former the flock is treated as a unit; in the latter the individual bird or family becomes the unit. In general practice this project does not necessitate trapnesting.

The purpose of the project was to determine whether it is possible to maintain or improve body weight, feather color, egg production factors, hatchability, and size, shape, and color of eggs without pedigreeing but through the annual introduction of new blood from reliable sources.

There is a very large group of commercial poultrymen, reproducing their own flocks and selling hatching eggs and baby chicks, who would like to retain or develop the above characteristics in their flocks and maintain them at as high a point of efficiency as possible, but who do not wish to resort to the technical methods required in pedigree breeding or even to maintain selected breeding pens for cockerel production. As the majority of layers in the State comes from these flocks, the more efficient they become the better for the industry.

With the results of this project decidedly positive, its general adoption would mean a great saving in the production of good chicks by this group of poultrymen, many of whom are now trapping a portion of their flocks without adequate returns. Furthermore, pedigree breeders who furnish the hatching eggs or breeding cockerels under this plan will be rewarded to a degree at least for the large expenditure of time, money, and energy they are putting into their breeding program.

General Plan

Hatching eggs were purchased for three successive years (cockerels the fourth year), from which enough breeding males were produced for the entire breeding flock. The pullets from these eggs were housed separately and their performance recorded as a check on their flock brothers. Well-selected eggs, pullets' 25-ounce, hens' 27-ounce, were stipulated when ordering. The eggs received were from trapped flock matings, the $15 to $18 per 100 grade.

The eggs were secured from reliable breeders who were known to be following an approved breeding program and whose stock was giving a good account of itself either at egg-laying contests or in the hands of their clients, or both.

The new blood was secured from a different source each year, in order to take advantage of hybrid vigor.

No hens and cocks were used, but the foundation pullets the first year and the hybrid pullets thereafter were mated to the new-blood males.

General Managerial Practices

Hatching Period

A glance at Table 2 shows that the hatching period each year extended over a period of several weeks. This permitted a more careful selection of eggs than would have been possible with only one or two hatches, but made it more difficult to compare early maturity in each generation.

Rearing

All birds used in this project were brooded in colony houses and grown on a good grass range. The brooding and rearing units were reasonably small and the grass was good throughout the season. Growing shelters were used for the overflow from the brooder houses. From the close of the brooding period, cracked corn and mash were kept in open hoppers, accessible to the chicks at all times.

Housing

The adult birds were housed in pens 9 by 14 feet, with an opening 5 by 5 feet for each pen. The houses, therefore, were far from being comfortable in the coldest weather. During the breeding season, doors between pens were thrown open allowing freedom of mating for both males and females.

Feeding

The birds were allowed to balance their own rations from hoppers containing whole corn, whole oats, and mash.

Elimination

As this project does not entail trapnesting, the following methods were used to eliminate from the flock undesirable specimens, those that would not be suitable for the reproduction of the flock. All pullets on the range were carefully handled and only the choicest specimens were placed in the laying houses. In most cases this included about 75 to 80 percent of the pullets raised. All small or backward pullets and those which were not good representatives of the flock were discarded.

Maturity.— All birds were either toe punched or banded, and those not showing evidence of laying or not being about ready to lay at 210 days of age were eliminated from the flock, as this was the only method whereby early maturity could be determined and maintained.

Body Weight.— For the first two years, each bird was weighed the first of each month from October 1 to May 1; but the last two years it was felt that not very much could be gained by continuing the weighing after the birds were mated. All birds not weighing over 5½ pounds or nearly 6 pounds at sexual maturity or soon thereafter were eliminated from the flock. It is interesting to note that the numbers eliminated under body weight and under maturity requirements were about equal.

The last two years nearly all birds that did not show a gradual gain in body weight from the time they were housed until the breeding season, and especially those that had lost one half pound or more during any month, were eliminated from the flock.

Cessation of Production.— Birds that stopped laying for any great length of time for any cause whatever were not allowed to remain in the flock.

Broodiness.— No broodiness was shown in any of these flocks; but had it made its appearance, the broody birds would have been removed before or during the hatching season.

General Appearance.— From the time the pullets were housed in the fall until the close of the breeding season, specimens not meeting the standards on general appearance were removed from the flock. This included birds showing unusual fading in feather color, injuries, and the lack of those qualities associated with thrift and vigor. However, very few birds were removed for these causes.

Weighing Eggs

All eggs from the flock for the first three days of each month were weighed and the average computed. This has proved experimentally to be a fair measure of egg size in a flock, provided the percentage production is normal during these periods.

Mortality

Definite records were not kept for mortality and its causes throughout the period, as this was not considered to be one of the main factors at the beginning of the work. It can be said, however, that the mortality in this flock was probably not so great as the general average for the entire college flock. Cannibalism did not break out in any of these flocks except the first one, when four or five birds were lost one day.

Selection of Males

At broiler age about three times the number of males needed for the breeding pens were reserved, attention being given to size, type, vigor, color, and general uniformity. The elimination of undesirable specimens was continued throughout the growing season and fall months. Those finally placed in the breeding pens weighed from 8½ to 9½ pounds. The use of males above that weight was avoided in order to keep away from the meat or beefy class. Uniformity in type, color, and general appearance was adhered to closely.

Selection of Hatching Eggs

Eggs were set weekly, and size, shape, and color were the bases of selection. In most instances not more than 75 to 80 percent of the eggs gathered were placed in the incubator. The past two years the average weight of eggs on the incubator trays was close to 27 ounces to the dozen. As all small birds and in most instances those of medium size had been removed from the flock, but few small eggs were produced.

Discussion and Results

Chart 1 gives the set-up for the four-year period. This shows the number of pullets housed each year, the number mated, the number of eggs (new blood) purchased each year, the number of males mated, and the number of sisters tested. The new blood flocks are designated as A, B, C, and D[1] for the four years, respectively, and are referred to as such.

---

[1] D = Experiment Station flock.

The 55 original pullets were from the experiment station flock, discarded because of family size, egg size, and possible deficiencies in other characteristics — in general, a fairly good commercial flock in all respects except egg size.

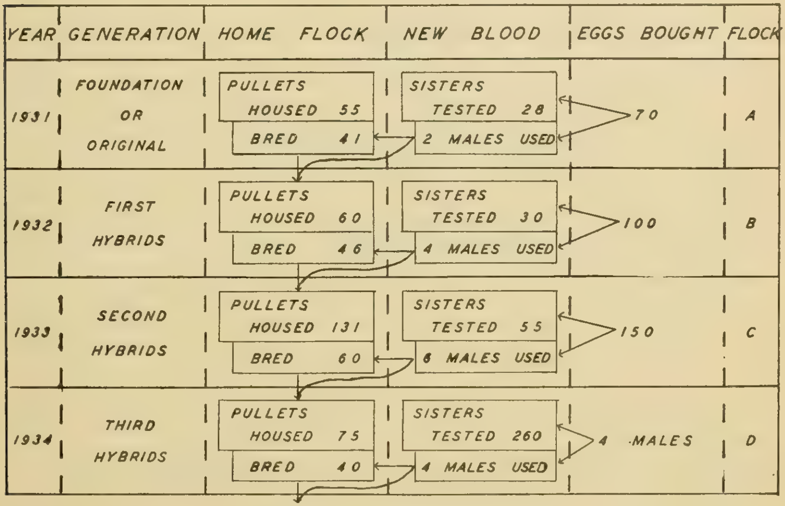

YEAR
GENERATION
HOME FLOCK
NEW BLOOD
EGGS BOUGHT
FLOCK
1931
FOUNDATION OR ORIGINAL
PULLETS HOUSED 55
BRED 41
SISTERS TESTED 28
2 MALES USED
70
A
1932
FIRST HYBRIDS
PULLETS HOUSED 60
BRED 46
SISTERS TESTED 30
4 MALES USED
100
B
1933
SECOND HYBRIDS
PULLETS HOUSED 131
BRED 60
SISTERS TESTED 55
6 MALES USED
150
C
1934
THIRD HYBRIDS
PULLETS HOUSED 75
BRED 40
SISTERS TESTED 260
4 MALES USED
4 MALES
D

Chart 1. The General Plan.

Sister Performance

Each year the flock sisters of the males reserved for breeding were housed separately and a record of their performance kept. Table 1 gives these data: number of pullets, body weight and egg weight taken the first of each month from housing time till the birds were mated, and monthly production.

The performance of the sisters is a good index of the quality of the flock selected for new blood. A and B were selected for egg size, a weakness in the foundation pullets, and also with the view of maintaining production. Following the use of these males, the weakest point in the flock was color, and Flock C was chosen particularly for the purpose of improving this characteristic. Although this flock did not average so high as A and B in all respects, being low in early maturity, intensity, and hatchability as was suspected, yet the pullets from these males mated to the second hybrid generation gave a good account of themselves. It must be borne in mind that Flock C pullets were tested during the very severe fall and winter of 1933-34.

Table 1 shows also progress made from year to year in the three important factors recorded: body weight, egg weight, and production. Had the project been started with a flock of moderate or low quality, very material gains would have been anticipated; but as the foundation flock was made up of experiment station birds that had been carefully bred for nearly 20 generations, merely maintaining the level of the main factors and increasing egg size would have been

TABLE 1.—PERFORMANCE RECORDS.

Month	Year Hatched	Generation	Original Flock and Hybrids					New Blood Sisters				
			Average Weight			Production		Flock	Number of Birds	Body Weight Pounds	Egg Weight Ounces per Dozen	Percent Production
			Number of Birds	Body Weight Pounds	Egg Weight Ounces per Dozen	Number of Birds	Percent Production					
October....	1931	Foundation flock	55	....	....	...	54	A	28	....	....	31
	1932	First hybrids	60	5.73	20.9	60	42	B	30	5.81	21.6	66
	1933	Second hybrids	132	5.83	21.8	131	51	C	53	5.07	21.0	26
	1934	Third hybrids	73	5.40	22.1	72	44	D	260	5.73	22.1	69
November ...	1931	Foundation flock	52	5.97	21.3	52	67	A	28	5.81	20.8	59
	1932	First hybrids	48	6.05	22.4	48	74	B	25	6.51	23.0	78
	1933	Second hybrids	130	6.37	23.1	86	57	C	52	5.61	22.5	38
	1934	Third hybrids	72	6.10	23.1	50	69	D	255	6.10	23.2	69
December....	1931	Foundation flock	47	6.16	22.6	47	64	A	28	6.27	22.7	67
	1932	First hybrids	48	6.35	23.5	47	72	B	25	6.84	23.9	60
	1933	Second hybrids	86	6.69	23.9	84	55	C	42	5.77	23.4	52
	1934	Third hybrids	50	6.90	24.2	49	63	D	248	6.40	24.1	61
January......	1931	Foundation flock	47	6.14	23.3	47	60	A	28	6.27	23.7	70
	1932	First hybrids	47	6.51	24.2	46	66	B	25	6.88	24.3	63
	1933	Second hybrids	83	6.68	25.4	62	45	C	29	6.03	24.8	58
	1934	Third hybrids	49	6.90	24.7	47	58	D	243	6.44	....	53
February.....	1931	Foundation flock	41	6.27	23.7	41	49	A	26	6.30	23.4	58
	1932	First hybrids	46	6.56	24.6	46	64	B	25	6.94	24.6	53
	1933	Second hybrids	62	....	26.2	60	56	C	28	....	25.0	49
	1934	Third hybrids	41	....	25.2	41	34	D	..	....	....	..
March.......	1931	Foundation flock	40	6.55	24.2	40	66	A	25	6.35	24.5	73
	1932	First hybrids	45	6.56	24.9	44	76	B	24	7.10	24 8	77
	1933	Second hybrids	...	....	....	60	60	C	...	....	...	63
	1934	Third hybrids	...	....	....	41	47	D	...	....	....	..

highly satisfactory. However, the records show a steady advance in body and egg weights. With the exception of lower production in the second hybrid generation, which was influenced very greatly by unfavorable weather conditions during the fall and winter of 1933-34, fecundity was very satisfactory.

Hatchability

Experimentation has shown that hybridizing with strains as well as with breeds gives a decided improvement in hatchability. But in order to show definitely the difference in hatchability between the flock sisters of the males used and the foundation or hybrid flocks each year, a number of flock sisters were placed with the hybrid females so that they would be served by the same males. It was necessary to trapnest the females during the breeding season in order to keep the eggs separate. Table 2 shows that the hybrid eggs hatched much better than the pure-strain eggs except in the 1935 flock when hatchability was adversely affected by an outbreak of coryza. As the average hatchability at the college plant in 1935 was 55 percent, a 75 percent hatchability for the hybrid eggs is evidence of vigor and high hatching power. These hatchability results for 1935 are presented in order that the data may be complete; but from an experimental point of view they are valueless on account of the coryza influence.

TABLE 2.—HATCHING DATA—PERCENTAGE OF FERTILE EGGS.

Hatching Date	1932		1933		1934		1935	
	A Males		B Males		C Males		D Males	
	Foundation Females	A Sisters	First Hybrid Females	B Sisters	Second Hybrid Females	C Sisters	Third Hybrid Females	D Sisters
3/1	....	100.0	86.0	81.0	....	....	....	....
3/8	....	70.0	95.0	65.0	92.0	46.1	....	....
3/15	....	68.9	95.0	70.0	92.3	50.0	71.4	77.7
3/22	90.6	75.0	91.0	82.0	88.7	65.2	76.2	57.0
3/29	81.1	77.7	95.0	87.0	83.0	64.0	81.8	71.4
4/5	88.5	90.0	....	89.0	84.3	73.0	76.4	100.0
4/12	94.5	80.0	....	....	89.2	83.0	70.8	83.3
4/19	89.1	93.3	....	....	....	....	72.7	88.8
4/26	89.8	78.6	....	....	....	....	76.4	83.3
5/1	....	....	....	....	....	....	84.2	42.8
Average	88.9	81.5	92.4	79.0	88.25	63.55	75.7	75.5

Experiment Station Flock	1933	1934	1935
3/5	76.0	70.8	73.3
3/12	79.0	72.9	77.2
3/19	77.0	79.2	81.7
3/26	82.0	83.3	81.5
4/2	86.0	82.1	81.8
4/9	81.0	79.3	83.8
4/16	83.0	80.6	83.7
4/23	86.0	81.7	81.9
Average	81.2	79.6	81.3

Evidence of Hybrid Vigor

It is reasonable to expect less hybrid vigor in the crossing of strains than in the crossing of breeds; likewise less in the crossing of strains that have been bred along similar lines than in those produced under breeding programs where aims and practices are more divergent. Although all flocks involved in this project, with the exception of Flock C, were produced under almost identical breeding programs, yet definite evidence of hybrid vigor is found.

In the case of body weight and egg size, based upon November and December weights, the hybrid flocks in every instance showed a gain over the average of the parents, the sisters' average being taken as a measure for the sires. Even the January weights, after rigid selection had taken place, indicated hybrid vigor in two cases out of the three in both body weight and egg size.

In the consideration of hatchability there is no question as to the part played by hybrid vigor, for the hybrid flocks were consistent in the production of eggs having a higher hatchability than those produced by pure lines, and their eggs hatched from 10 to 15 percent better than those from the sires' flock sisters, with the exception of Flock D where coryza greatly influenced hatchability. These data indicate that a hatchability of 79 to 82 percent is about normal for the pure strains used. However, in a project of this kind one cannot be too careful in drawing conclusions as there are two factors that may cause error: first, variations in breeding programs for these flocks; and second, the practical methods used in eliminating undesirable specimens from housing time until the breeding season.

Summary

It appears that production qualities and hatchability can be built up or maintained in a flock by the annual introduction of new blood from reliable sources. Success will depend upon the following factors:

1. The care with which the foundation flock is selected.
   Only flocks with satisfactory records of performance should be selected for this purpose.
2. The ability to obtain new blood that will raise the level of the factors sought.
   This should come from breeders who are known to be following an approved breeding program and whose stock is giving a good account of itself either at egg laying contests or in the hands of their clients or both.
3. The elimination of undesirables before the breeding season begins.
4. The persistency with which the details of the program are followed.

Hybrid vigor made its appearance in egg weights, bird size, hatchability, and possibly in production if an accurate measure could have been used. It was not of great significance in bird and egg weights, but of much importance in hatchability.

The cost of this method of flock improvement is insignificant compared with the cost of pedigree breeding, as 300 eggs purchased annually will supply breeding males for a flock of 750 females and will also add a possible 100 to 125 quality pullets to the flock.

Publication of this Document Approved by Commission on Administration and Finance
5M-11-'35. No. 5999.

140
326

VIRGINIA POLYTECHNIC INSTITUTE
AGRICULTURAL [illegible] LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No 326 December, 1935

VIRGINIA AGRICULTURAL EXPERIMENT STATION

Naphthalene
as a
Greenhouse Fumigant

By W. D. Whitcomb

Naphthalene fumes may be used to kill certain greenhouse pests, particularly the common red spider, which are not controlled by the standard fumigating materials containing nicotine or hydrocyanic acid gas. This bulletin is intended to supply specific information regarding the conditions under which greenhouse fumigation with naphthalene is both safe and effective.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

NAPHTHALENE AS A GREENHOUSE FUMIGANT

By W. D. Whitcomb, Research Professor of Entomology

INTRODUCTION

In a greenhouse where confined gases will penetrate all available areas and where they can be discharged with a reasonable amount of labor and expense, fumigation is the ideal method of pest control. Unfortunately, however, the standard fumigating materials containing nicotine and hydrocyanic acid gas, which satisfactorily control the majority of greenhouse insect pests, do not effectively control the common red spider at concentrations and exposures which can be safely used on most greenhouse plants. Naphthalene fumes have a specific toxic action on the common red spider and other pests; and when certain factors such as temperature, relative humidity, dosage, and length of exposure are controlled, fumigation with naphthalene is a safe and effective treatment on many species of greenhouse plants.

DESCRIPTION OF NAPHTHALENE

Naphthalene is an organic chemical compound having the symbol $C_{10}H_8$ and is produced by the destructive distillation of coal. When pure it forms flat colorless crystals having a penetrating but not unpleasant odor and a burning aromatic taste. The fumes are irritating to the eyes, usually inducing tears, but reasonable exposure to them is not harmful. Naphthalene melts at 80.1° C. (176.2° F.) and boils at 217.9° C. (424.2° F.). The crystals volatilize slowly at about 70° F. and this action increases with the amount of water vapor in the air. They are insoluble in cold water but can be dissolved in ether, alcohol, and other organic solvents.

Naphthalene finds its greatest use in the dye industry where, in combination with other chemicals, it is used in the manufacture of various colors, especially red and yellow. It is prepared for commerce in a crude form (bags) both domestic and imported, flake form (barrels), dyestuff (bags), and as the well-known moth balls (barrels) where it may be combined with camphor. The retail price for the commercial forms ranges from 8 to 12 cents a pound. A resublimed form (100 percent pure) is available in limited quantities at a considerably greater cost.

Naphthalene which is to be used for fumigating living plants should be approximately 95 percent pure. The principal impurities are forms of unrefined coal tar, the fumes of which are injurious to plant life. Crude naphthalene, which is the cheapest commercial grade, contains variable quantities of these impurities and its analysis is neither guaranteed nor constant. Resublimed naphthalene is the purest form which is commercially available and was used in the first work with this material for greenhouse fumigation. Commercial flake naphthalene is a very nearly pure product which has been found entirely satisfactory for fumigating, and this form was used in the experiments reported herein.

HISTORY OF NAPHTHALENE AS AN INSECTICIDE AND INSECT REPELLENT

On Field Crops

Twenty or more years ago, naphthalene was more generally used for preventing insect damage on trees, vines, and vegetables in Europe than in America. According to Bourcart (4) at least a dozen mixtures included naphthalene in their formulas and their uses were widespread. In the sprays, washes, and dips, the naphthalene was generally combined with coal tar and lime, while some form of sulfur or copper was occasionally added. Some of the materials of this nature which were frequently used were known as Crouzel's Anticryptogamic, Balbiani's Ointment, Occidine, and Rathay Bouillie. Solutions of naphthalene, 1 part in 8 parts of alcohol or benzene (1 pound in a gallon), were also used. Dusts for the treatment of growing plants were prepared by mixing naphthalene with sulfur, pyrethrum, lime, or ashes. For killing and repelling soil insects such as wireworms, naphthalene was mixed with sand or with sawdust and sown with the seed or worked into the soil with the manure. More recent literature indicates that naphthalene is less popular, probably because it has been supplanted by more effective materials.

In the United States, one of the oldest remedies for preventing injury to stored clothing, wool, fur, and leather by clothes moths or carpet beetles is storing them with naphthalene. Back (1, 2) recommends 1 pound in each 10 cubic feet for this purpose. To control fleas in a building, Bishopp (3) recommends using 5 pounds in each ordinary sized room.

More recently, a wash prepared with soap, naphthalene, flour, and water for painting the trunks of trees to prevent oviposition by the flat-headed apple tree borer has been recommended in Michigan (11). A somewhat similar emulsion of naphthalene and cottonseed oil was used by Snapp (15) in Georgia for peach borer control with somewhat unsatisfactory results.

The carrot rust fly was effectively controlled by Glasgow (5) by broadcasting 6 applications of crude naphthalene at the rate of 400 pounds per acre, and Maughan (9) in New York used it quite successfully to control onion thrips in the field. The experiments of Weigel et al. (20) have shown that naphthalene when stored with gladiolus corms provides a very effective and practical control of the gladiolus thrips.

The larvae, pupae, and eggs of the Japanese beetle are killed by thoroughly mixing the soil with naphthalene flakes (19). When used at the rate of 5 pounds for each cubic yard for potting soil, and 1,000 pounds per acre or 23 pounds per 1,000 square feet in cold frames, hotbeds, or nursery rows, naphthalene constitutes an approved treatment for disinfecting the soil of this pest.

It appears that the use of this material for insecticidal purposes is now increasing in this country.

On Greenhouse Crops

Among the first records of the use of naphthalene as a greenhouse fumigant are those discussed in the reports of the Experimental and Research Station, Cheshunt, Herts, England. Here, Speyer (16) in 1923, after preliminary laboratory work with a large number of volatile liquids and volatile solids dissolved in liquids, found sufficient encouragement in white flake naphthalene to use it on a practical scale. At first, the naphthalene was dissolved in tetrachlorethane, this solution being poured on the ground and on the steam pipes with variable results. Later, flakes were mixed with sulfur and spread on the steam pipes with more satisfactory results.

In 1924, broadcasting the naphthalene along the walks of the greenhouse (17) became the approved method of application, using from 2 to 12 pounds in each greenhouse 100 feet long. Continued studies showed that exposures of about 72 hours were advisable and that air temperatures above 74° F. with high relative humidities were preferable. In 1925, the normal dosage was placed at 6 pounds in each 100-foot greenhouse, and a standardized grade of naphthalene known as "Grade 16" which would pass through a screen containing 16 meshes to the inch was prepared especially for fumigating. Practically all of this work was the result of efforts to find more effective methods for combating the common red spider[1] on greenhouse cucumbers, and apparently this treatment became well established in England.

This special grade was evidently the first form of naphthalene to be prepared commercially strictly for fumigating purposes, being handled by Geo. Munro, Ltd., who supplied many tons to the cucumber growers in the Lea Valley section about 1925.

About 1926 Hartzell (6) and the author began experimenting with naphthalene as a greenhouse fumigant, and the encouraging results of the preliminary work led several florists in the northeastern United States to fumigate with this material on a practical scale. This work also led to the manufacture and distribution in 1928 by the Fuller System, Inc., Woburn, Massachusetts, of the first commercial naphthalene fumigant to be available in this part of the country. In February, 1932, a patent (U. S. 1,845,977) was issued on this material and methods for its use in greenhouses. This patent apparently covers only the manufacture and use of mixtures composed of naphthalene and other coal tar derivatives rather than naphthalene alone, since the application was not filed until more than four years after the publication of the reports of Speyer (16), Parker (10), and Hartzell (6).

About 1930, mixtures containing naphthalene and ground tobacco stems were prepared and used extensively for combating soil inhabiting pests in greenhouse beds and benches. These materials when spread on or mixed with the surface soil were quite effective for eliminating earthworms, snails, sow bugs, and similar soil inhabiting animals, but were not entirely satisfactory for combating pests on the aerial parts of plants.

EQUIPMENT FOR FUMIGATING WITH NAPHTHALENE

The application of artificial heat in some form to control the rapidity with which naphthalene is vaporized is the common method of using this material for greenhouse fumigation in Massachusetts. Many lamps and stoves have been devised for this purpose. Most of these devices supply sufficient heat to melt the naphthalene and maintain it in a liquid condition without boiling, while others increase and control vaporization by circulating warm air over crystallized naphthalene.

Parker (10) used a paraffin lamp over which an inverted cone supporting a pan containing the naphthalene was suspended. Hartzell (6) surrounded an ordinary house lamp with a ventilated sheet iron cone to support the pan of naphthalene. Some growers varied this by substituting a sheet iron chimney with a mica door for the glass chimney on a house lamp. The Fuller System,

---

[1] *Tetranychus telarius* L.

Inc., manufactured a two-wick oil stove with a sheet iron chimney and pan support. Some growers used Union oil stoves with satisfactory results. The rapidity of vaporization in these stoves is controlled by adjusting the height of the flame.

Hartzell (7) used a three-heat electric hot plate on which was placed a porcelain or sheet iron dish to hold the material, and the writer varied this by constructing a frame over the hot plate which would hold the dish at various heights above the heating unit in order to regulate the amount of naphthalene volatilized in a given time. Hartzell and Wilcoxon (8) developed a naphthalene saturator in which the greenhouse air was blown over large quantities of naphthalene balls for 8 to 15 hours, the concentration of the fumes being governed by the length of time the saturator was in operation. The writer has extended this idea by devising an electric naphthalene fumigator in which the air is heated to about 165° F. (just below the melting point of naphthalene) by passing it through a slowly revolving fan in front of which is placed a series of electrically heated resistance wires. This heated air circulates through a cabinet containing trays permitting exposure to the air of a large part of the crystals in them. The heated air speeds up the volatilization of the crystals and the concentration is governed by the amount of crystals in the trays and by the length of time the equipment is operated. As with the Hartzell and Wilcoxon saturator there is no danger of boiling or burning the naphthalene; good circulation of the fumes is provided by the fan, and many of the more susceptible plants which have suffered injury when fumigated by the lamp method have been treated safely with this equipment.

In 1933, the Hartzell and Wilcoxon saturator (8) was improved to use liquid solutions containing naphthalene. In this apparatus a solution containing a known quantity of naphthalene dissolved in a light motor oil was pumped over a cone in such a way that the air became charged with naphthalene as it was forced through the solution falling from the cone. The amount of naphthalene in the solution governed the concentration of the naphthalene vapor in the air.

In the average greenhouse the most practical equipment appears to be the two-wick oil stove as shown in Plate I.

Experimental Fumigation Chamber

The majority of the experiments at the Waltham Field Station were conducted in a specially constructed gas-tight chamber containing 1,500 cubic feet, located within a standard greenhouse section. This chamber is about 14 feet long and 10 feet wide with cement floor and side walls 2 feet high on which is constructed a greenhouse frame with 30 x 16 inch glass set in putty. The door and door frame are beveled and closed with a pressure slide latch. Circulation is maintained by an electric fan operated at slow speed. The naphthalene was vaporized over an electric hot plate as described above. A constant temperature was maintained by supplying heat from steam pipes, controlled by a thermostat operated by air pressure from an automatic compressor. Constant relative humidity was maintained by the operation of a horse-hair regulator supplied with 30 pounds air pressure controlling a spray of water from a nozzle delivering 8 gallons per hour. An electric fan operating in an exhaust opening with a hinged door enabled the fumes to be evacuated quickly when the fumigation was completed.

ACTION OF NAPHTHALENE FUMES

On Insects and Spiders in General

Reports by Speyer (16) and Hartzell (6) show that naphthalene has a selective toxicity to the common red spider and the greenhouse thrips (p. 19 footnote), and as a fumigant gives better control of red spider with safety to many plants than other known fumigants. Therefore, the experimental studies and the practical development of naphthalene fumigation have been based largely on its effectiveness as a control for the common red spider.

The toxicity of naphthalene to insects and spiders is apparently dependent upon a relatively long exposure in air containing naphthalene vapor. The action of these fumes on the insect is paralytic and the first evidence is shown by a lack of control of the legs and other appendages even though they can be moved freely. The cause of this action is not definitely known, although it appears that the gradual paralysis is due to the partial exclusion of oxygen from the respiratory system. With continued exposure paralysis increases until death results, and there is no evidence that the body tissues are burned or seared in any way. Four or five days after death the bodies of the fumigated insects and spiders collapse and dry.

The high temperature and high relative humidity which are necessary for successful naphthalene fumigation provide conditions tending to increase respiration and body metabolism in animals, thus aiding the penetration and toxic action of the naphthalene fumes. It is also apparent that naphthalene fumes penetrate the chorion of the egg and kill the embryo in the same way that the active stages are killed.

Early in the studies it was observed that the different stages of the red spider possessed a varying degree of resistance to fumigation, and experiments were therefore conducted with eggs, larvae, nymphs, and adults.

On Red Spider Eggs

In 1927, Read (12) reported that eggs were killed by an eight-hour exposure to a saturated atmosphere of naphthalene at 100° F., and that the time required to kill them decreased as the temperature and atmospheric moisture increased. However, this temperature is higher than can be maintained under practical conditions.

At Waltham newly laid eggs failed to hatch after two or more fumigations of six hours duration using 3 ounces of naphthalene per 1,000 cubic feet at 75° F., as shown in Table 1.

Table 1. — Mortality of Red Spider Eggs on Carnation Leaves after Fumigation with Naphthalene.

Temperature 75°F. Relative Humidity 80—90 percent. Exposure 6 hours.
Dosage 3 ounces per 1000 cubic feet.
Waltham, Massachusetts. April 1930.

Number of Fumigations	Number of Eggs	Percent Hatched
None	46	89.13
1	48	12.50
2	43	0
3	46	0
4	48	0

The age or degree of incubation of the eggs influences their susceptibility to fumigation, as shown in Table 2. In this experiment, eggs were divided into two groups: those which had become a deep straw color and showed the developing embryo within, and those which had been laid during the previous 24 hours. These eggs were placed in short glass tubes filled with plaster of Paris, which permitted a small amount of moisture to reach them when the tubes were set on damp sand (14). Since more than 80 percent of the unfumigated eggs hatched, these tubes apparently provided satisfactory conditions for incubation. Under these conditions, none of the older eggs hatched after one or more fumigations, while it required four fumigations to prevent all of the newly laid eggs from hatching. Fumigated eggs developed a slightly darker color than the untreated eggs, but this change in color was not always consistent and in many cases it was impossible to determine the effect of the treatment until long after the eggs should have hatched under natural conditions.

TABLE 2. — MORTALITY OF NEW AND OLD EGGS OF RED SPIDER AFTER FUMIGATION WITH NAPHTHALENE.

Dosage 3 ounces per 1,000 cubic feet.
Temperature 80°F. Relative Humidity 90 percent. Exposure 6 hours.
Waltham, Massachusetts. March 1930.

Number of Fumigations	Number of Eggs Observed	CONDITION OF EGGS AFTER TREATMENT							
		5 Days		10 Days		15 Days		20 Days	
		Dead	Hatched	Dead	Hatched	Dead	Hatched	Dead	Hatched
		New Eggs							
None	20	1	2	2	13	3	16	4	16
1	10	0	0	4	1	6	1	9	1
2	10	6	1	7	1	8	1	9	1
3	10	4	0	6	1	6	1	9	1
4	10	7	0	10	0	–	–	–	–
		Old Eggs							
None	20	2	10	3	17	–	–	–	–
1	10	4	0	4	0	8	0	10	0
2	10	3	0	6	0	7	0	10	0
3	10	3	0	3	0	7	0	10	0
4	10	4	0	6	0	7	0	10	0

On Active Stages of Red Spider

An examination of infested plants after fumigation which has resulted in an incomplete kill of common red spiders usually shows a predominance of larvae, second stage nymphs (deutonymphs), and adult males among the living spiders. The results summarized in Table 3 indicate that these forms have a slightly greater resistance to naphthalene fumigation than the first stage nymphs (protonymphs) and the adult females. This may be partially explained in the case of deutonymphs by the fact that many of them at the time of fumigation are in the first or proto-quiescent molting period of suppressed activity, when they are obviously less susceptible to toxic fumes. In the case of the adult males, it is apparent that they are the most active of all stages and are able to select most quickly any protective parts of the plant where the fumes penetrate with difficulty. Red spider larvae are quite easily killed by naphthalene fumes and those individuals which are so commonly present a few days after treatment have hatched from eggs which survived the exposure. It has also seemed very probable that many of the adult females which survive were in the second molting period during fumigation.

Table 3. — Percentage of the Different Active Stages of Common Red Spider Killed by Naphthalene Fumigation.

Dosage 3 ounces per 1,000 cubic feet.
Temperature 80°F. Relative Humidity 95 percent. Exposure 6 hours.
Waltham, Massachusetts. March 1930.

Stage of Development	One Fumigation		Two Fumigations	
	Number of Spiders	Mortality Percent	Number of Spiders	Mortality Percent
Larva	169	69.82	102	96.08
Protonymph	167	74.20	109	100.00
Deutonymph	41	53.68	74	100.00
Adult Male	33	33.33	4	100.00
Adult Female	44	72.50	48	100.00
Total	454	70.28	333	98.81

FACTORS INFLUENCING THE EFFECTIVENESS OF NAPHTHALENE FUMIGATION

Crystal naphthalene volatilizes slowly at any temperature suitable for growing plants, but a sufficiently rapid volatilization for controlled fumigation takes place only at temperatures near the melting point of the crystals (176.2°F), and the experiments reported herein are based almost entirely on the volatilization of melted naphthalene. In certain apparatus (p. 5) the naphthalene is volatilized by blowing over the crystals air at normal greenhouse temperatures or at moderately high temperatures, but these methods are effective only when the exposure is two or three times longer than if the naphthalene is melted.

Roark and Nelson (13) have calculated that the greatest amount of naphthalene vapor which can exist in 1,000 cubic feet of air at 77° F. is 0.04 pound (0.64 ounces or 18.14 grams) and that this constitutes saturation. The amount necessary for saturation increases slightly as the temperature and vapor pressure increase, becoming approximately 21 grams at 80° F. and 80 percent relative humidity.

Dosage

The maintenance of a sufficient concentration of naphthalene vapor for several hours is necessary for successful fumigation; and the correct amount of naphthalene crystals to be vaporized in a given cubical unit in order to make and maintain that concentration varies with the leakage, adsorption, air drafts, temperature, and relative humidity. Therefore, any standard dose which is determined under experimental conditions may necessarily be varied when applied in actual practice in different greenhouses or under different conditions in the same greenhouse.

In a practically gas-tight fumigation chamber during a six-hour exposure 4 and 5 ounces of naphthalene per 1,000 cubic feet have been vaporized without causing noticeable injury to resistant plants such as carnations. However, the volatilization of such an excess above the computed saturation point causes supersaturation which can exist only for a short time without recrystallization or other physical and chemical changes. In the experimental fumigation chamber 2 and 3 ounces per 1,000 cubic feet have frequently killed 95 to 100 percent of the common red spider in one 6-hour fumigation and have resulted in practically perfect control in two fumigations. With high relative humidity, 1½ ounces per 1,000 cubic feet was equally effective in two and three treatments, and occasionally in one treatment. A dosage of 1 ounce per 1,000 cubic feet was not consistently effective in less than three successive fumigations.

The effectiveness of these dosages is somewhat decreased under average greenhouse conditions, and the most satisfactory dosage under normal conditions is 2 to 3 ounces per 1,000 cubic feet.

Exposure

The effectiveness of naphthalene fumigation is determined by the length of time the red spiders are exposed to an atmosphere which is partially or completely saturated with naphthalene vapor. Wilcoxon et al. (21) have shown that satisfactory control of red spider resulted from an exposure of 14 to 16 hours to a 13 percent saturated atmosphere in one case, and an approximately one-half saturated atmosphere in another case, when unmelted naphthalene was vaporized in special equipment. However, when the naphthalene crystals are melted and complete saturation of the atmosphere is obtained, a 6-hour exposure is satisfactory.

As shown in Table 4, the vaporization of ¼ ounce of naphthalene each hour failed to have an appreciable effect on red spider until after 3 hours when ¾ ounce of naphthalene had been vaporized. At this time the concentration approached saturation, and thereafter the kill increased each hour until a mortality of 88 percent was obtained after 5 hours exposure. When the spiders were first exposed 2 hours after fumigation began, at which time ½ ounce of naphthalene per 1,000 cubic feet had been vaporized, a mortality of 85 percent was reached after an exposure of 4 hours, 3 hours of which were in a nearly saturated atmosphere. When red spiders were first exposed after the vaporization of ¾ ounce per 1,000 cubic feet in 3 hours had built up a calculated saturated atmosphere, an 85 percent kill resulted after 3 hours exposure. A mortality of 85 percent was also obtained in 3 hours when the spiders were first exposed after 1 ounce of naphthalene had been vaporized in 4 hours, since in both cases the air was approximately saturated when the spiders entered. However, a 2-hour exposure to saturated atmosphere in which 1 ounce of naphthalene had been vaporized killed 68 percent of the red spiders, but only 24 to 34 percent were killed by equal exposures to less saturated atmosphere in which ½ or ¾ ounce had been vaporized.

TABLE 4. — PROGRESSIVE MORTALITY OF COMMON RED SPIDER ON POTTED CARNATION PLANTS FUMIGATED WITH NAPHTHALENE

Naphthalene vaporized at rate of ¼ ounce per 1,000 cubic feet each hour.
Temperature 75°F. Relatively Humidity 85 percent.
Waltham, Massachusetts. October 1935.

Length of Time Fumigation Had Been in Progress when Plants were First Exposed	Total Naphthalene Vaporized when Plants Were Removed	Percentage Mortality of Red Spider After Exposures of —					
		1 Hour	2 Hours	3 Hours	4 Hours	5 Hours	6 Hours
	Ounces						
At the beginning	¼	14.19					
	½		20.32				
	¾			32.78			
	1				52.00		
	1¼					83.89	
	1½						94.36
2 Hours	¾	16.38					
	1		33.94				
	1¼			55.20			
	1½				85.83		
3 Hours	1	19.39					
	1¼		24.35				
	1½			84.68			
	1¾				92.79		
4 Hours	1¼	16.66					
	1½		68.75				
	1¾			85.08			
	2				97.58		

NOTE: Percentage mortality of red spiders on plants not fumigated, 7.54.

From this experiment it is apparent that normal fumigations under favorable conditions do not give a reasonable control (85 percent dead) until the red spiders have been exposed for 3 hours or longer to an atmosphere in which at least ¾ ounce of naphthalene per 1,000 cubic feet has been vaporized and retained.

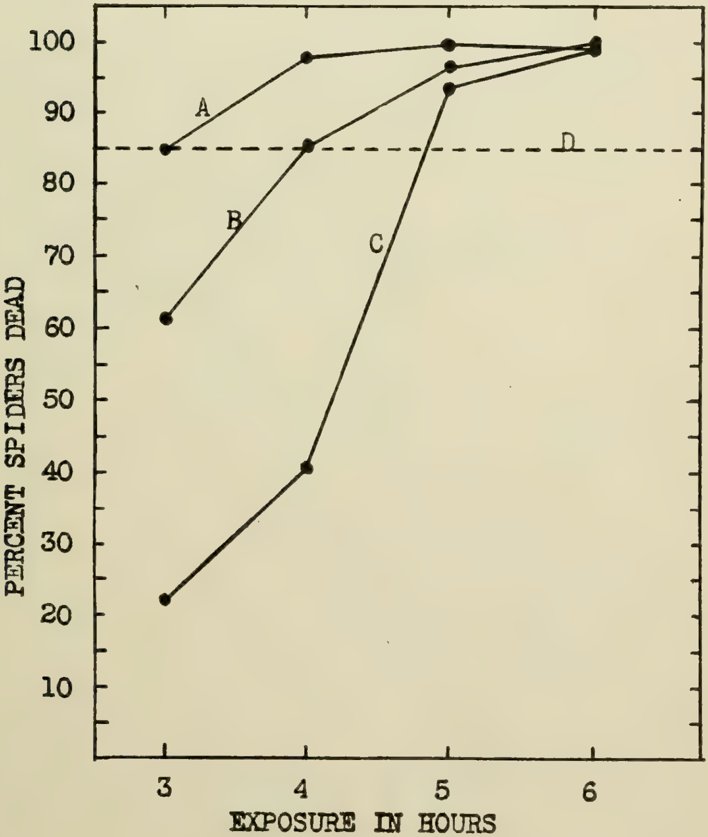
Similar results are indicated in Figure 1 where the time required to build up a calculated saturated atmosphere was decreased by increasing the rapidity with which a normal effective dosage for a 6-hour exposure was vaporized. In this experiment the vaporization of 3 ounces of naphthalene in 3 hours at the rate of 1 ounce each hour killed 85 percent of the red spiders in 3 hours; but at the rate of ¾ ounce each hour for 3 hours followed by ¼ ounce each hour for 3 hours, an exposure of 4 hours was required to kill 85 percent of the red spiders; and at the rate of ½ ounce each hour for 6 hours, a 5-hour exposure was necessary to effect an equal mortality.

Manipulation of the fumigant in this way is practical only in extremely tight greenhouses under favorable conditions and with careful attention to detail by experienced operators.

Although experiments under ideal conditions in a special fumigation chamber indicate that an exposure of 3 to 5 hours is frequently effective, actual practice shows that the efficiency of naphthalene fumigations is usually less under average greenhouse conditions and an exposure of 6 hours is necessary.

Figure 1 — Mortality of Common Red Spider When Naphthalene is Vaporized at a Heavy Uniform Rate during the First Half of the Exposure, and at a Light Uniform Rate, or Omitted, During the Last Half of the Exposure as Compared With a Uniform Vaporization During the Whole Fumigation.

Dosage 2 Ounces per 1,000 Cubic Feet. Exposure 6 Hours.
Temperature 75° F. Relative Humidity 75 Percent.
Waltham, Massachusetts. 1935.



A — 1 ounce each hour for 3 hours — none for 3 hours
B — ¾ ounce each hour for 3 hours — ¼ ounce each hour for 3 hours
C — ½ ounce each hour for 6 hours
D — Commercially effective mortality from 1 fumigation

Interval Between Fumigations

Frequently, three or four successive fumigations within 10 to 15 days are required to give satisfactory control. When successive fumigations are necessary, the interval between treatments should not be longer than one week during which time the majority of the spiders will have hatched from eggs not killed by previous fumigations. In Table 5 the results of fumigations at intervals of one, two, and three days show a slight advantage where the fumigations were made on successive days. However, the mortality after two- and three-day intervals is high and the differences are insignificant. It is,therefore, apparent that within a reasonable period successive fumigations should be made when the weather conditions are most suitable rather than at any predetermined intervals.

TABLE 5. — MORTALITY OF COMMON RED SPIDER AFTER FUMIGATIONS WITH NAPHTHALENE AT INTERVALS OF 1, 2, AND 3 DAYS BETWEEN FUMIGATIONS.

Dosage 2 ounces per 1,000 cubic feet.
Temperature 75°F. Relative Humidity 80 percent.
Waltham, Massachusetts. March 1931.

	MORTALITY OF RED SPIDERS, PERCENT		
Number of Fumigations	1 Day between Treatments	2 Days between Treatments	3 Days between Treatments
1	69.34	38.70	31.64
2	72.82	79.87	90.67
3	100.00	95.79	98.83
4	100.00	92.59	94.44
None (check)	25.25		

Count made 5 days after fumigation.

Operation and Number of Stoves

The uniform vaporization of naphthalene throughout the total period of exposure is necessary for successful operation, and this is governed by the amount of heat generated by the stove. In coal-oil stoves this depends on the height of the flame. In general, the flame should be about one-third high but the proper adjustment of the stove wicks for each dosage can be determined only by trial. Therefore, it is recommended that when making a 6-hour fumigation the total amount of naphthalene crystals for each stove be divided into six equal parts and that one part be added each hour. When the calculated hourly dose is weighed, its volume can be marked in a small pan or cup which can then be used as a measure for all subsequent doses. By adjusting the stove wicks to vaporize the hourly dosage during the first hour, the rate of vaporization should be uniform during the remainder of the fumigation. After several fumigations many operators learn by observation the correct rate of vaporization and can safely apply the total pan dosage at the beginning, but even then it is strongly advised that frequent examinations be made in order to readjust any wicks which may have varied from the proper position.

In the average greenhouse, circulation during fumigation is obtained only by the movement of warm and cold air and by the buoyancy of the fumes. Observations have indicated that diffusion is greater in large compartments than in small ones. In greenhouses containing 50,000 or more cubic feet, satisfactory results are obtained by using one stove in each 7,000 cubic feet or fraction thereof. In smaller compartments it is advisable to place a stove in each 5,000 cubic feet.

The vapors from fuming naphthalene tend to diffuse with a mushroom effect and frequently they follow the pitch of the roof upward before rolling downward to envelop the plants. It is, therefore, advisable to place stoves at about the same height as the top of the growing plants in order to avoid an excessive concentration of vapor near the stoves, and also to place them in two rows, each row being about one-third of the distance from the sides toward the center.

Light

Exposure to naphthalene vapor during sunlight and photosynthetic action is much less injurious to plants than a similar exposure to such fumigants as hydrocyanic acid gas and volatile nicotine. The most tolerant species of plants growing under normal conditions have consistently shown no detrimental effects from naphthalene fumigation in sunlight, and many of the less tolerant species have been safely fumigated in bright light when other conditions were favorable. When unfavorable conditions exist, however, fumigation in sunlight may aggravate any injury which results from the treatment. In the spring when greenhouse plants are soft, following forced growth in continued cloudy weather, they are less resistant than at other times and should not be fumigated in bright sun.

It is often advisable to take advantage of sun heat for maintaining the necessary temperature, and in cool weather day-time fumigations of carnations and other tolerant plants are satisfactory. In hot weather when excessive temperatures result from closing the ventilators during the day, fumigations should be started in late afternoon and continued into the night until the necessary period of exposure is completed. The less resistant species of plants should be fumigated on cloudy days or at night. When a fumigation is started on a cloudy day and the sun shines before the exposure is completed, it is advisable to discontinue the treatment of susceptible plants; but the fumigation of tolerant plants may continue in the sun until the temperature rises to 95° F.

Temperature

Recrystallization of naphthalene fumes which occurs at 72° F. or lower may be injurious to plants, and temperatures of 95° F. or higher if maintained for several hours are unfavorable to plant growth. Therefore, the temperature limits for fumigation with naphthalene are established at 72° to 95° F.

Theoretically, the capacity of air to hold naphthalene vapor increases as the temperature increases (13), and the greater amount of naphthalene in the air at a higher temperature should kill insects and spiders more easily and quickly. This theory is substantiated by Table 6, which shows that 26.48 and 45.30 percent more common red spiders were killed by fumigations at 90° than at 70° F., and that the treatment was noticeably more effective at 80° than at 70°.

TABLE 6. — RELATION OF TEMPERATURE TO THE EFFECTIVENESS OF NAPHTHALENE FUMIGATION ON THE COMMON RED SPIDER.

Dosage 1 or 1½ ounces per 1,000 cubic feet.
Relative Humidity 75 percent. Exposure 6 hours.
Waltham, Massachusetts. 1934–35.

Temperature	Dosage 1 Ounce		Dosage 1½ Ounces	
	Number of Spiders	Mortality Percent	Number of Spiders	Mortality Percent
70° F. . .	278	52.51	291	61.85
80° F. . .	286	83.91	278	88.84
90° F. . .	137	97.81	120	88.33

Many other experimental fumigations have indicated that variations in temperature between 75° and 85° F. have no significant influence on the effectiveness of the fumigation, and that the permissible range of temperature during fumigation is limited from a practical standpoint by the effect on the plants rather than by the effect on the toxicity of the fumigant.

One or more accurate thermometers placed at strategic locations in the greenhouse should be read frequently.

Air pockets in corners and around certain benches are frequently cooler than the average air temperature, and the temperature in such places should be watched carefully. When the temperature rises above 95° F. and can be lowered only by ventilation, the fumigation should be discontinued.

During commercial fumigations a comparatively constant temperature between 75° and 85° F. is favorable to effective results, and provides a satisfactory leeway for correcting unexpected temperature changes.

Relative Humidity

Relative humidity or the amount of moisture in the air is usually comparatively high in the greenhouse and can be quite easily regulated by careful watering of the soil. When pipe heat is used, however, it is difficult to maintain a constant high humidity, and under such conditions it is frequently necessary to wet the walks and pipes every two or three hours.

Hygrometers or psychrometers for determining the relative humidity should be placed at representative positions in the greenhouse and consulted frequently. A satisfactory type of hygrometer consists of a dry thermometer, a wet thermometer, and a tube of water for supplying the bulb of the wet thermometer with moisture. When both the dry and the wet thermometer read the same, the relative humidity is 100 percent. By interpreting the readings of the two thermometers on a simple chart which accompanies such equipment, the relative humidity is easily determined.

The effect of humidity on the red spider is well shown in Table 7. In this experiment where no fumigant was used, two and three exposures of 6 hours each showed that the mortality of the spiders increased with each increase in the relative humidity, and that this mortality was from 24 to 36 percent greater at 90 percent relative humidity than at 60 percent.

TABLE 7. — MORTALITY OF RED SPIDER AT DIFFERENT HUMIDITY, WITHOUT FUMIGANT.

Temperature 80° F. Exposures 6 hours each.
Waltham, Massachusetts. April 1932.

Relative Humidity Percent	Mortality of Red Spider, Percent	
	2 exposures	3 exposures
90	54.28	59.13
80	36.36	49.74
70	29.36	44.44
60	18.65	35.05

In experimental fumigations of active red spiders in which the relative humidity was controlled at 60, 70, 80, and 90 percent, the mortality of the spiders again increased as the relative humidity was increased. As shown in Table 8, this was especially significant when the dosage of naphthalene was 1 ounce or 1½ ounces per 1,000 cubic feet; but when the dosage was increased and the mortality became correspondingly higher, the influence of the humidity decreased and was negligible.

TABLE 8. — RELATION OF RELATIVE HUMIDITY TO EFFECTIVENESS OF NAPHTHALENE FUMIGATION AGAINST RED SPIDERS.

Dosage, 1 or 1½ ounces per 1,000 cubic feet.
Temperature 80° F. One exposure.
Waltham, Massachusetts. April 1931.

Relative Humidity, Percent	Mortality of Red Spider, Percent	
	Dosage 1 ounce	Dosage 1½ ounces
90	75.58	99.45
80	70.17	99.20
70	69.81	64.91
60	56.37	42.85

A similar effect on red spider eggs was noted in other experimental fumigations with 1½ ounces of naphthalene per 1,000 cubic feet at 80° F. These fumigations, which killed all of the active red spiders, also killed the eggs at 90 percent relative humidity but permitted 53 and 57 spiders (percentage not determined) to hatch from the eggs fumigated at 75 and 65 percent relative humidity. Further evidence that red spider eggs are more resistant to naphthalene fumigation as the humidity is decreased is indicated by the general abundance of red spider larvae after fumigation at the lower relative humidities, summarized in Table 9. In these experiments the exact number of eggs and larvae present before fumigation is not known, but the evident greater number which survived the treatments at 60 and 70 percent relative humidity is significant.

Table 9. — Relative Abundance of Red Spider Larvae on Plants Fumigated with Various Dosages of Naphthalene at Different Relative Humidity.

Examined 3 days after fumigation. Temperature 80° F.
Waltham, Massachusetts. 1931–32.

Relative Humidity Percent	Dosage per 1,000 cu. ft. Ounces	Number of Red Spider Larvae Alive After —		
		1 exposure	2 exposures	3 exposures
90	1	***	*	*
	1½	*	0	0
	2	0	0	0
	3	*	0	0
80	1	**	***	0
	1½	*	0	0
	2	*	0	0
	3	*	0	0
70	1	****	*	0
	1½	***	*	0
	2	*	*	0
	3	**	0	0
60	1	***	****	**
	1½	****	**	0
	2	*	***	0
	3	****	***	****

KEY:

* — 1 to 10 red spider larvae alive
** — 11 to 25 red spider larvae alive
*** — 26 to 50 red spider larvae alive
**** — More than 50 red spider larvae alive

These experiments and several years' experience have proved definitely that a relative humidity of 75 to 80 percent is desirable for the most satisfactory results, and every effort should be made to maintain approximately that condition during fumigation with naphthalene.

Unfavorable Conditions

Few, if any, commercial greenhouses are so nearly air tight and provide so ideal conditions for fumigating as the experimental fumigation chamber in which most of the experiments reported herein were conducted. Leakage, adsorption, air pockets, and failure to maintain satisfactory and constant temperatures and relative humidities all tend to decrease the effectiveness of the treatments. In the experiments reported in Table 10 all of these factors contributed to the results, especially since the fumigations were made in the daytime when favorable conditions are usually more difficult to maintain. The percentage of dead spiders after one and two fumigations is lower than should be expected, but this experiment provides a good example of the occasional need for four successive fumigations to obtain effective control of the red spider.

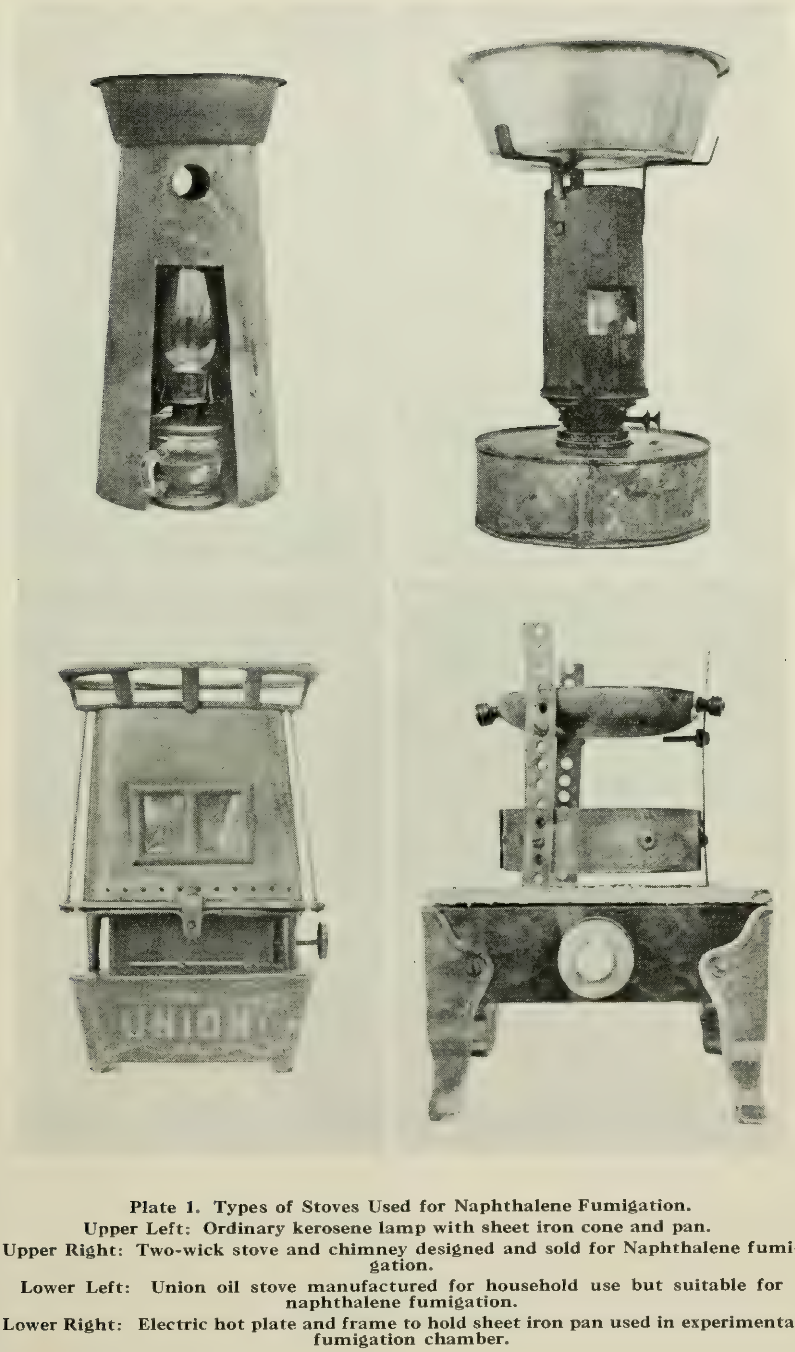


Plate 1. Types of Stoves Used for Naphthalene Fumigation.

Upper Left: Ordinary kerosene lamp with sheet iron cone and pan.

Upper Right: Two-wick stove and chimney designed and sold for Naphthalene fumigation.

Lower Left: Union oil stove manufactured for household use but suitable for naphthalene fumigation.

Lower Right: Electric hot plate and frame to hold sheet iron pan used in experimental fumigation chamber.

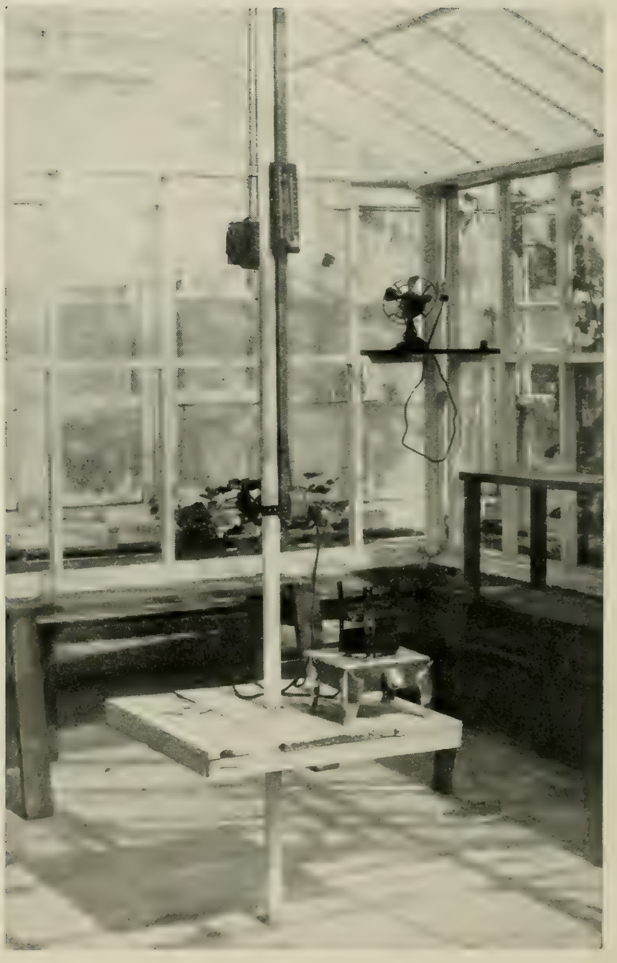


Plate 2. Interior of Experimental Fumigation Chamber, Waltham Field Station. Showing electric hot plate vaporizing unit, fan for circulation, and air pressure thermostat.

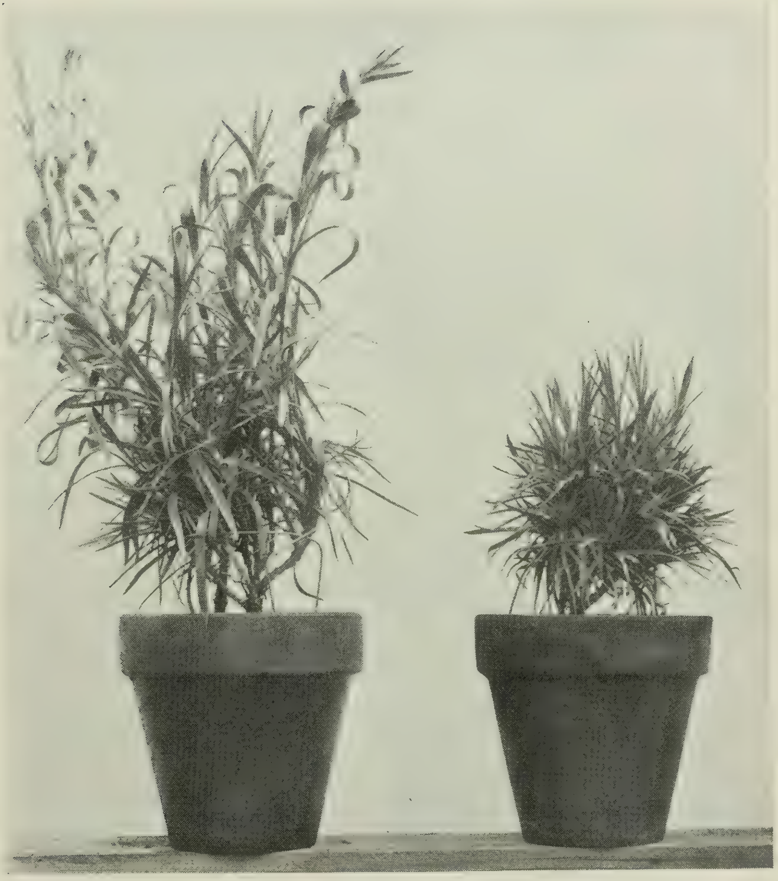


Plate 3. Effect of Red Spider Injury to Carnation.
Left: Plant fumigated with naphthalene and free from injury; growth normal.
Right: Plant not fumigated; heavily infested with red spider; growth stunted.

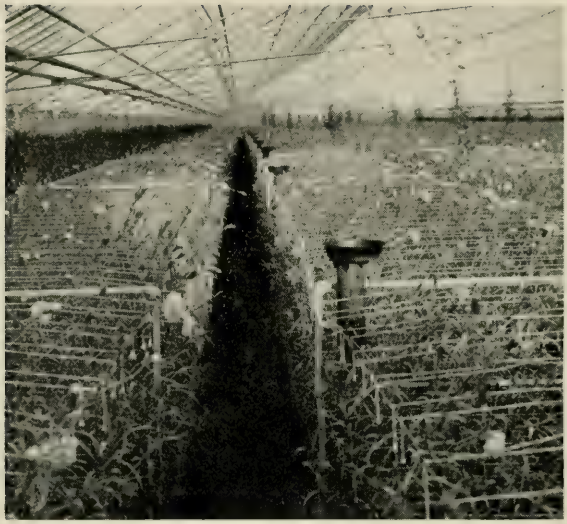


Plate 4. Arrangement of Vaporizing Stoves for Naphthalene Fumigation in a Commercial Greenhouse.

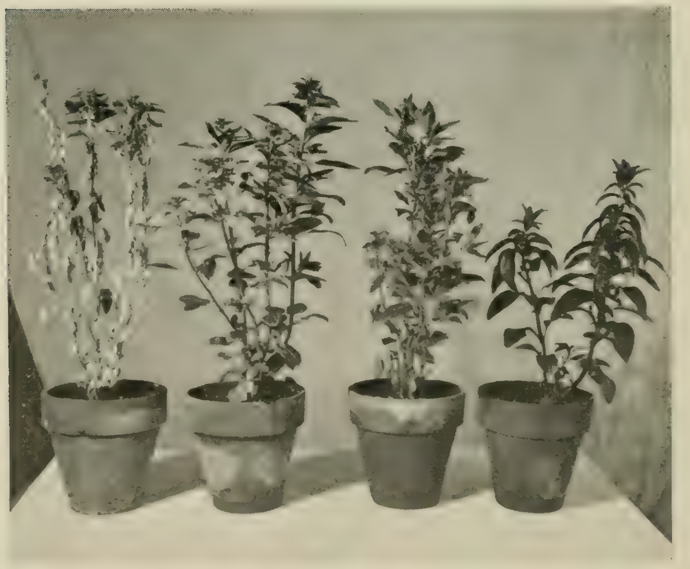


Plate 5. Type of Injury Resulting from Improper Naphthalene Fumigation. Snapdragon Plants.
Left: Severely injured. Center: Slightly injured. Right: Uninjured.

Table 10. — Effectiveness of Naphthalene Fumigations under Unfavorable Conditions in Commercial Greenhouses.

Dosage 2 ounces per 1,000 cubic feet. Crop, Carnation.
Temperature 75°–90° F. Relative Humidity 60–80 percent.
Waltham, Massachusetts. October and November 1931.

Number of Fumigations	First Series		Second Series	
	Number of Spiders	Mortality Percent	Number of Spiders	Mortality Percent
1	387	13.69	253	9.09
2	253	35.57	525	57.52
3	285	65.61	396	59.59
4	227	97.78	357	94.30
None (check)	632	9.18	172	0

COMBINATIONS OF NAPHTHALENE AND OTHER MATERIALS

Speyer in England (16, 17) experimented with naphthalene combined with other chemicals without securing results which were definitely superior to those obtained from naphthalene alone.

Naphthalene and Paradichlorobenzene

Early in the present studies it was apparent that some method for reducing the recrystallizing temperature of the fumes was desirable. Paradichlorobenzene has a lower recrystallizing temperature than naphthalene but is usually injurious to plants in effective doses. A mixture containing 15 percent paradichlorobenzene was apparently safe and could be used satisfactorily at 68° F. or above, while naphthalene alone should be used only at 72° F. or above. Such a mixture was manufactured commercially and used extensively. Experimental fumigations, however, have failed to show that this mixture is significantly superior to naphthalene alone, especially after the two or three successive fumigations which were necessary to secure a reasonable mortality of red spider. Table 11 shows the results of comparative fumigations in adjoining compartments of a commercial greenhouse.

Other Combinations

In 1933 naphthalene in a solid solution with sulfur was reported by Wilcoxon, Hartzell, and Youden (21) to be very effective in a special naphthalene saturator with less injury to sensitive plants.

The same investigators used naphthalene dissolved in motor oil very effectively and safely with exposures of 16 hours in apparatus especially designed for this purpose, and found that the concentration of naphthalene in the air was governed by the amount of naphthalene dissolved in the oil, thus permitting more control over the dosage during fumigation.

Recently, two commercial fumigants similar to naphthalene have been developed and used in Massachusetts. These fumigants are liquids containing benzene ring chemicals closely related to naphthalene in combination with other materials. They are vaporized over stoves and lamps and, in general, require the same conditions as those recommended for naphthalene fumigation. Experiments indicate that, although the vapor from these fumigants does not recrystallize and become injurious at the lower greenhouse temperatures, comparatively high temperature and humidity are advisable for maximum efficiency. Under favorable conditions they appear to be slightly more effective against red spider than naphthalene and will give satisfactory control of this pest with one or two fumigations.

Table 11. — Comparative Effectiveness of Fumigation with Naphthalene and with Naphthalene-Paradichlorobenzene 85–15 for Controlling Common Red Spider.

Temperature 78° — 85° F. Relative Humidity 80–90 percent.
Waltham, Massachusetts. March 1930.

Fumigant	Dosage per 1,000 cu. ft. Ounces	Mortality of Red Spider, Percent			
		1 Exposure	2 Exposures	3 Exposures	4 Exposures
Naphthalene . .	2	12.26	58.58	87.87	98.27
Naphthalene . . 85 Paradichlorobenzene 15	2	16.07	53.90	90.68	94.48
Naphthalene . .	3	27.32	97.26	99.61	99.53
Naphthalene . . 85 Paradichlorobenzene 15	3	41.66	98.33	100.00	100.00
None (check) . .		4.50			

Compatibility of Naphthalene Fumes with Fungicides and Other Insecticides

Like other fumigants, naphthalene fumes, as used in greenhouse fumigation, leave no residue on the plants which might be injurious to plants when followed by applications of fungicides or other insecticides.

In experimental fumigations by the writer, no injury to carnations resulted when 40 percent free nicotine liquid was combined with naphthalene in the vaporizing pan, and Wilcoxon et al. (21) report safe and effective fumigations with a combination of naphthalene and sulfur.

Carnations bearing the residue from previous applications of Bordeaux mixture have been fumigated with naphthalene regularly in this section without noticeable injury from the treatment.

CONTROL OF OTHER PESTS

As previously stated, naphthalene fumigations are especially effective for combating the red spider. Thrips are also quickly and easily killed by this treatment, but heavy infestations of several other greenhouse pests may be only partially controlled or can be more effectively combated by other means. When regular fumigations with naphthalene are made to control the common red spider, however, other greenhouse pests will be held in check and the crop maintained in a general insect-free condition.

The greenhouse thrips[1] and the onion thrips[2] are very effectively controlled, and usually with less exposure than is necessary to kill the red spider. Complete control is not always obtained, however, because many thrips hide in the unopened buds where they are partially protected from the fumes. The gladiolus thrips[3] is controlled by naphthalene fumigation; but the gladiolus, especially when forced in the greenhouse, may be slightly injured, and the treatment is therefore not recommended.

The green chrysanthemum aphid,[4] the black chrysanthemum aphid,[5] the green peach aphid,[6] and the bean aphid,[7] the last two being frequently found on carnation, have been completely controlled by two or more fumigations, and it is probable that the treatment is equally effective against all species of aphids likely to be present in the greenhouse. However, one fumigation with naphthalene is not so effective against aphids as one fumigation with nicotine or hydrocyanic acid gas, and the value of naphthalene for this purpose is principally to control aphids when it is being used to combat other pests.

Adult white flies[8] are killed to about the same extent that aphids are killed; but as is the case when nicotine fumes or hydrocyanic acid gas are used to combat this pest, the majority of the larvae and pupae survive, and repeated treatments or spraying in addition to fumigating may be necessary to give practical control.

The citrus mealy bug[9] is killed in large numbers by successive fumigations with naphthalene and frequently the soil under heavily infested plants will be covered with their bodies after treatment. However, ten fumigations have not entirely freed the plants of these pests, and the treatment cannot be recommended as a practical control measure.

All stages of the cyclamen mite[10] are resistant to naphthalene fumigation. Furthermore, it is the habit of these pests to live within the unopened buds of flowers and leaves, even working deeply into the crown where they are protected from sprays and fumigants. Frequent fumigations at intervals of 5 to 7 days reduce injury by this pest but will not give complete control. The broad mite,[11] a closely related species which is frequently found on the same plants, lives on the exposed surfaces of the leaf and is more effectively controlled by naphthalene fumigation. Smith (18) found that the eggs of this mite are very resistant to this treatment, but by repeating fumigations at least three times at intervals of 5 to 7 days to kill the active stages, this mite was quite satisfactorily controlled.

Bulb mites[12] when exposed to two strong fumigations became sluggish but revived in 24 hours, and mites which were in the soil or in cavities in decayed bulbs were unaffected. In no case did the fumigant penetrate the soil sufficiently to control soil-inhabiting animals. Sowbugs, centipedes, and millipedes are frequently killed when exposed to naphthalene, but large numbers of them are usually sufficiently protected in their hiding places to survive fumigations.

The moths of the greenhouse leaf tyer,[13] the rose leaf roller,[14] and cutworm species,[15] have been killed by naphthalene fumigation, but the larvae of these insects are seldom killed and the treatment does not constitute a satisfactory control measure.

---

[1] *Thrips tabaci* L.

[2] *Heliothrips haemorrhoidalis* Bouche

[3] *Taeniothrips gladioli* M. S.

[4] *Colorodoa rufomaculata* Wilson

[5] *Macrosiphoniella sanborni* Gillette

[6] *Myzus persicae* Sulz.

[7] *Aphis rumicis* L

[8] *Trialeurodes vaporariorum* Westwood

[9] *Pseudococcus citri* Risso

[10] *Tarsonemus pallidus* Banks

[11] *Tarsonemus latus* Banks

[12] *Rhyzoglyphus hyacinthi* Boisd.

[13] *Phlyctaenia rubigalis* Guen.

[14] *Cacoecia rosaceana* Harris

[15] Family Noctuidae

INJURY TO PLANTS BY NAPHTHALENE FUMIGATION

Unfortunately, naphthalene fumigation is not entirely safe to use on all species of plants or under all conditions, and injury may result if certain precautions are not observed.

Causes of Injury

The usual factors which induce plant injury are (1) fumigation of intolerant species, (2) failure to provide favorable atmospheric conditions (temperature, relative humidity, and light), and (3) improper adjustment of the vaporizing apparatus. These factors actually influence the effect of the fumigation by causing either too great a concentration of the fumes or too long exposure to them.

An excessive concentration of the fumes is most injurious when the melted naphthalene is permitted to boil, causing an unequal distribution and producing temporary supersaturation. There is also evidence that the fumes from boiled naphthalene are broken down by the excessive heat into gases which are more harmful to plants than are the fumes from crystal or melted naphthalene. Poor circulation in the greenhouse resulting in air pockets is often responsible for injurious concentrations of naphthalene in corners. This condition may also be caused indirectly by the recrystallization of naphthalene fumes due to low temperature. The deposit of recrystallized crystals does not injure the foliage immediately, but as each crystal again volatilizes, a strong concentration of naphthalene fumes is created at the place of contact and the plant tissue is burned at that spot.

Injury from too long an exposure to naphthalene fumes may result when the greenhouse remains closed over night after the stoves have been shut off. Possible injury from this cause should be avoided by changing the air as soon as possible after the fumigation is completed, especially when treatments are made on two or three successive days.

Appearance of Injury

Plants which have been exposed to the fumes from boiled naphthalene, or to too great a concentration of fumes from vaporized naphthalene, show wilted and darkened areas on the foliage and stems soon after the injury has occurred. In a few hours the injured areas, which may be the size of a pinhead or may include all the leaves and tender stems of the plant, turn to the characteristic white color of dead but not diseased plant tissue. Usually, the new leaves and tender buds are injured first; and when severe or moderate injury has occurred, new growth generally breaks out below the injured part of the stem, especially on plants which produce buds at the leaf axils.

Injury from too long an exposure to naphthalene fumes is less well defined but usually appears as a premature yellowing and falling of the older leaves. This has been especially noticeable on woody plants such as rose, gardenia, citrus, and oleander, as well as on coleus and some of the larger chrysanthemums. Yellow leaves similar to those following fumigation are also caused by too forceful syringing or by improper growing conditions, and it frequently appears that the naphthalene only hastens and aggravates the injury, which is primarily due to the poor health of the plant.

Occasionally colored blooms and buds, especially carnations and roses, have been bleached by a prolonged exposure to naphthalene, injury of this kind being more frequent when the growth is abnormally soft and tender.

TOLERANCE OF PLANTS TO NAPHTHALENE FUMIGATION

The tolerance of plants to naphthalene fumes differs greatly. Hartzell (6 and 7) has classified a large number of species and varieties according to their susceptibility in his experiments, and most of the species which are grown in New England greenhouses have been fumigated experimentally by the writer. As a result, certain species of plants are known to tolerate the treatment and others very definitely will not, thus dividing them into three general groups as follows:

(1) Those which are very resistant and are not noticeably injured by slightly excessive concentrations or long exposures. Fumigation recommended as a regular treatment.

(2) Those which have consistently been injured and apparently will not tolerate the treatment. Fumigation not recommended unless plants are to be destroyed.

(3) Those which fall between Group 1 and 2, being tolerant to naphthalene during favorable conditions especially in experimental fumigations but exhibiting a tendency to be injured when slightly unfavorable conditions exist. Fumigation is recommended for this group only when insect injury is severe and when satisfactory control of atmospheric conditions can be maintained. Improved apparatus for fumigating will greatly reduce the danger of injury to plants in this group.

A list of some of the more important plants which fall in Groups 1 and 2 is given in Table 12. All other species are arbitrarily placed in Group 3 since they have been neither outstandingly tolerant nor susceptible in experimental and commercial fumigations.

Table 12. — Tolerance of Some Common Greenhouse Plants to Naphthalene Fumigation.

Group 1. Tolerant Plants	Group 2. Susceptible Plants
Aspidistra	Asparagus Ferns
Begonia (Chatelaine)	Easter Lily
Boston Fern (Nephrolepsis)	Freesia
Cactus (Opuntia)	Fuchsia
Calendula	Geranium
Carnation	Gladiolus
Centaurea	Iris
Coleus	Kalanchoe
Cyclamen	Narcissus
Dahlia	Nicotiana
English Ivy	Oxalis
Sansevieria	Physalis
	Poppy
	Radish
	Rose (Rambler and Buttonhole)
	Tomato
	Tulip

TABLE 13. — STATUS OF NAPHTHALENE FUMIGATION ON MOST IMPORTANT GREENHOUSE CROPS.

Crop	Naphthalene Fumigation Recommended	Most Important Pests	Controlled by Naphthalene Fumigation	Tolerance to Treatment	Type of Injury if any	Remarks
Begonia (Chatelaine)	Yes	Cyclamen Mite Broad Mite	Slightly Yes	High	Foliage burn	Several successive fumigations necessary.
Calendula	Yes	Red Spider	Yes	High	Foliage burn	Seldom needs treatment.
Carnation	Yes	Red Spider Thrips	Yes Yes	Very high	Slight bleach	Most effective treatment. No injury with favorable conditions. See p. 24.
Chrysanthemum	Conditionally	Thrips Chrysanthemum Midge	Yes No	Low	Blind or deformed buds and yellow leaf.	Not all varieties injured. See p. 25.
Cyclamen	Yes	Cyclamen Mite Broad Mite	Slightly Yes	High	Crippled buds.	Several successive fumigations necessary.
Gardenia	Yes	Mealybug Red Spider	Partially Yes	Medium	Yellow leaf and leaf drop.	Heavily infested plants most likely to be injured.
Lilies	No	Thrips	Yes	Low	Foliage burn	Easter lilies, gladiolus, freesias, tulips, narcissi, likely to be injured. Callas are more tolerant.
Rose	Conditionally	Red Spider Thrips	Yes Yes	Medium	Foliage burn and leaf drop.	Most favorable conditions necessary to avoid injury. See p. 25.

Snapdragon	Conditionally	Cyclamen Mite	Slightly	Medium	Foliage burn.	Most favorable conditions necessary to avoid injury.
		Broad Mite	Yes			
Sweet Pea	No	Red Spider	Yes	Low	Foliage burn and bud drop.	Occasionally fumigated, but tolerance is not consistent.
Cucumber	No	Red Spider	Yes	Medium	Tendril and leaf burn.	Tendrils injured first; fruit retains odor and taste. See p. 25.
		Thrips	Yes			
Tomato	No	Red Spider	Yes	Low	Foliage tip burn.	Fruit retains odor and taste. See p. 26.

When only one species of plant is grown in a section of greenhouse naphthalene fumigation can be adapted to the requirements of that crop, and frequently a treatment can be regulated to effectively fumigate two or more species growing in the same greenhouse. When susceptible plants are grown in the same section with those which can be fumigated safely, those likely to be injured should be removed during fumigation or the pests should be combated with sprays or dusts. It is not advisable to fumigate a section of mixed plants without regard for the degree of tolerance of the different species.

A summary of the recommendations for fumigating the principal greenhouse crops with naphthalene is given in Table 13.

The desirability of fumigating carnations, roses, chrysanthemums, cucumbers, and tomatoes is considered more frequently than the treatment of other crops and, therefore, the effect of naphthalene on these plants is described separately.

Carnations

Naphthalene fumigation is especially recommended for carnations, and fumigation with it or similar commercial preparations is now a universal treatment for this crop throughout New England. This plant is extremely tolerant to naphthalene and it has been used as the host plant in most of the experimental work with the common red spider. More than forty varieties and color strains have been fumigated with equal safety. During the winter, when there is an excess of cloudy weather, pink blooms have occasionally been faded or bleached slightly following fumigation, but since this effect has not been consistent, the naphthalene appears to be a contributing factor rather than the direct cause. Even should bleaching occur, the resulting loss or decreased value of one or two cuttings is far less than the damage done by an unchecked infestation of the common red spider. The most economical practice is to fumigate thoroughly in the fall so that the plants enter the winter blooming season free from insects and spiders which will not develop seriously at the winter growing temperatures of carnations.

When compared with water syringing as a means of red spider control, regular fumigations with naphthalene produced from 14 to 21 percent more marketable flowers from both good and poor crops of carnations, as shown in Table 14.

TABLE 14. — YIELD OF MARKETABLE FLOWERS FROM CARNATIONS RECEIVING NAPHTHALENE FUMIGATION AND WATER SYRINGE.

Waltham, Massachusetts.*

Season	Cutting Period	Total Flowers	Average Flowers per Plant: Naphthalene Fumigation	Average Flowers per Plant: Water Syringe	Gain in Fumigated Plot Percent
1929–30	Oct. 1 — May 20†	6,165	13.07	9.76	14.52
1930–31	Sept. 8 — May 13	2,748	6.17	4.00	21.32

*Records furnished by E. F. Guba from data secured in connection with studies of carnation blight (*Alternaria dianthi* S. & H.).

†Average date. Actual date on different benches varied from May 4 to June 3.

Many growers have questioned the effect of subjecting carnations to high temperatures and high relative humidity for 6 hours, but many experimental and commercial fumigations have fully demonstrated the ability of healthy plants to stand these conditions without apparent injurious results.

Roses

Common greenhouse roses of the hybrid tea type, such as Briarcliff, Talisman, and Templar, should be fumigated only when the most favorable conditions can be maintained. They cannot be treated with the heavy dosages or under the partially unfavorable conditions which are tolerated by carnations. Excessive concentrations of naphthalene vapor due to rapid volatilization or poor distribution will burn the new growth and must be avoided. Bleaching of pink varieties is less likely to occur on roses than on carnations. Leaves which have been loosened by forceful syringing invariably turn yellow after fumigation.

Rambler and polyantha type roses, which are frequently forced in pots in the greenhouse, are usually injured by normal fumigations and should never be treated.

Chrysanthemums

Following naphthalene fumigation, the buds of certain varieties of chrysanthemums are deformed or fail to develop. This blindness, which is similar to that caused by improper application of fertilizer, appears to be characteristic of this crop. The plants are especially susceptible during the period of bud formation. Repeated fumigations of buds which have developed from about half grown to full bloom have failed to cause this injury. Varieties appear to have different degrees of susceptibility, and in experimental fumigations the standards, Major Bonnafon, Halliday, and Friendly Rival, and the pompon Golden Nymph, were the most consistently affected, while injury to other varieties has been reported by growers. Blindness did not occur when special apparatus (p. 5) was used, but unless equipment of this nature is available naphthalene fumigation is not recommended for chrysanthemums, especially during the period of bud development and when the above-mentioned varieties are grown.

Cucumbers

Although naphthalene fumigation in the greenhouse was first used to combat the common red spider on cucumbers, this treatment is not now recommended for general use on this crop. The principal reason for discontinuing the practice was the fact that the fruit absorbed and retained the odor and taste of the naphthalene for several days. Much of this taste disappeared after a few hours in fresh air but invariably a sufficient trace of it remained to make the fruit objectionable to people with a sensitive taste. On this crop the tendrils are usually first to show injury, often being shrivelled when no other evidence is present, and this may be followed by burn on the margin of the leaves. Excessive concentrations may also injure the pistillate flowers and prevent development of the fruit. Fumigations of cucumbers soon after they are set in the beds and before they begin to bear will free the plants of pests without contaminating the fruit; and strong fumigations just before the vines are pulled out or when the house is empty is recommended as a means of eliminating thrips and the common red spider between crops.

Tomatoes

Tomatoes are more sensitive to naphthalene fumigation than cucumbers and should be given this treatment only when pest infestation is extremely severe. As with cucumbers, the disagreeable odor and flavor of the chemical is absorbed and retained by the fruit, especially after it begins to color. Injury first appears as a marginal foliage burn on tender new growth.

COST OF NAPHTHALENE FUMIGATION

Naphthalene fumigation is not an expensive operation. After the equipment for fumigating a greenhouse unit is available, the cost compares favorably with that of other effective fumigation treatments.

Permanent equipment consists of vaporizing units and a gas mask of some kind, but with ordinary care this equipment should last for 10 years or more, thus distributing the initial cost over a long period.

Practical vaporizing stoves can be purchased for $2.00 or $2.25 each, or satisfactory units can be assembled at home at a cost of 50 cents or more each, depending upon the ability and ingenuity of the individual. The only wearable parts in the stoves are the wicks, which should last for two or three years. Gas masks should be considered a convenience rather than a necessity since many operators do not use them. Furthermore, they have other uses and are valuable safety equipment for many emergencies.

Commercial flake naphthalene costs 8 to 12 cents per pound retail, and 2 to 3 ounces for each 1,000 cubic feet are used in a fumigation.

It is probable that some additional fuel will be necessary to maintain the required temperature but this will be variable and is difficult to estimate. Based on approximate figures in the experimental greenhouses, it would require in the coldest weather approximately 37 gallons of fuel oil at 6 cents per gallon, or ¼ ton bituminous coal at $7.00 per ton, to raise the temperature 15° to 25° F. above normal temperatures for a 6-hour fumigation period; while in cool weather about 12½ gallons of fuel oil at 6 cents per gallon, or 1/10 ton of bituminous coal at $7.00 per ton, would be sufficient.

Most fumigations are managed by the grower or his most reliable regular help so that no additional labor is necessary, but if additional labor is necessary an expense of 6 hours labor at 30 cents an hour should be charged to the fumigation.

An estimate of the cost for fumigating with naphthalene in a greenhouse 200 feet long, 30 feet wide, and 10 feet high (average), containing 60,000 cubic feet is as follows:

Initial Cost

	Maximum	Minimum
Stoves, 1 for each 7,000 cu. ft.:		
9 at $2.25 (purchased)	$20.25	
9 at .50 (homemade)		$4.50
Gas Mask	5.00	None
Totals	$25.25	$4.50

Operating Cost

	Maximum	Minimum
Naphthalene, 3 or 2 ozs. per 1,000 cu. ft.:		
3 ozs. per 1,000 cu. ft. — 180 ozs. or 11¼ lbs. at 10c	$1.125	
2 ozs. per 1,000 cu. ft. — 120 ozs. or 7½ lbs. at 10c		$0.75
Fuel for stoves:		
2 gals. kerosene at 17c	.34	.34
Additional fuel for heat:		
Cold weather — 37 gals. oil at 6c	2.22	
Cool weather — 12½ gals. oil at 6c		.75
Additional labor:		
6 hours at 30c	1.80	None
Total	$5.485	$1.84

PROCEDURE FOR FUMIGATING WITH NAPHTHALENE

Choose the time for fumigating according to the weather. When it is cool start the fumigation about 9 a. m. on cloudy days; when it is warm, start about 4 p. m. Do not fumigate on windy days.

Remove susceptible varieties of plants from the greenhouse whenever practicable.

Water all potted plants, wet the walks, and be sure that soil in the benches is moist, thus raising the relative humidity to about 80 percent as determined from a hygrometer or a psychrometer.

Close ventilators and stop drafts through broken or loose glass.

Raise temperature to 75° to 80° F., as determined from an accurate thermometer, and adjust heating equipment to maintain that temperature.

Determine the cubical contents of the house by multiplying the length by the width by the average height. Supply a stove for each 7,000 cubic feet in a large house, or for each 5,000 cubic feet in a small house, placing them just above the top of the plants.

Determine the amount of naphthalene crystals necessary for treatment at the rate of 2 or 3 ounces per 1,000 cubic feet, depending upon the tightness of the house. Determine the proportionate amount for each stove and divide this by 6 to give the amount for each stove for each hour. Mark this hourly dosage in a glass or cup which can be conveniently used as a measure.

Example: A house 200 feet long, 40 feet wide, 10 feet average height, contains 80,000 cubic feet. At the rate of 1 stove for each 7,000 cubic feet, use 12 stoves placed about 15 feet apart. At the rate of 3 ounces of naphthalene per 1,000 cubic feet, 20 ounces per stove (80 x 3 = 240 ÷12) is necessary and should be divided at the rate of 3⅓ ounces (20 ÷ 6) per stove per hour for 6 hours.

Light stoves and adjust wicks to a low flame, being sure that they do not blaze up in one corner.

Put one hourly dosage of naphthalene in each pan.

After one hour add another hourly quota to each pan, and if necessary adjust the flame of the lamp by raising the wick if some naphthalene remains or by lowering it if the material has vaporized before the required time. Repeat this operation each hour until six hourly doses have been vaporized.

If the melted naphthalene should boil or should vaporize in less than half the required time, it is usually advisable to stop the fumigation and change the air in the greenhouse; but if the naphthalene has vaporized too rapidly in only one or two lamps the danger of plant injury is not great and the fumigation can usually be continued after adjusting the lamps.

If the temperature unavoidably rises above 95° F. or drops below 70° F. during the exposure, the fumigation should be discontinued and the house ventilated.

When pipe heat is used to maintain the necessary temperature, the relative humidity may decrease rapidly making it advisable to wet the walks after the third hour.

After the fumigation is completed, the air in the greenhouse should be changed by opening the doors and ventilators. In cool weather this should be done gradually to avoid a rapid drop in the air temperature.

SUMMARY

Commerical flake naphthalene, costing 8 to 12 cents a pound, when vaporized in the greenhouse controls the common red spider and the greenhouse thrips very effectively and is a satisfactory method for combating these and other pests.

Naphthalene fumes kill by penetrating the respiratory system of insects and spiders causing paralysis and death.

Eggs of the red spider were killed by two or more successive fumigations using 3 ounces of naphthalene per 1,000 cubic feet for 6 hours, and old eggs were killed more quickly than newly laid eggs. The larva, protonymph, and adult female of the red spider appear to be more easily killed than other stages. Two successive fumigations at a dosage of 2 ounces or more of naphthalene per 1,000 cubic feet have resulted in practically perfect control of red spider under favorable experimental conditions. Dosages of more than 3 ounces of naphthalene per 1,000 cubic feet have frequently caused supersaturation and plant injury, and dosages of less than 2 ounces per 1,000 cubic feet have usually required more than two successive treatments to be effective.

In controlled experiments the vaporization and confinement of three-fourths ounce of naphthalene per 1,000 cubic feet produce a noticeable effect on the red spider, and an exposure to this concentration for three hours has killed 85 percent or more of these pests. Under average greenhouse conditions some of the fumes escape or are absorbed by the soil and benches so that the most satisfactory dosage is 2 to 3 ounces per 1,000 cubic feet, and a total exposure of 6 hours is recommended for effective results.

In commercial greenhouses where it is difficult to maintain favorable atmospheric conditions, three or four successive fumigations are frequently necessary to give effective control. The treatment is satisfactory whether the interval between fumigations is one, two, or three days, and the time to fumigate should be determined by suitable weather conditions.

Although various types of stoves, lamps, and special saturators are available for vaporizing naphthalene for fumigating, a two-wick coal-oil stove is the most practical under average greenhouse conditions. In these stoves the crystals are melted to increase vaporization but the melted naphthalene should never boil. A uniform vaporization can be obtained by dividing the total dosage for each stove into six equal parts and adding one part each hour, adjusting the wick so that each hourly quota is vaporized in one hour. In large greenhouses one stove unit should be used in each 7,000 cubic feet of space, but in small compartments a stove unit for each 5,000 cubic feet is advisable.

Resistant species of plants can be safely fumigated in the sunlight. In cool weather sun heat can be used to aid in maintaining the necessary temperature. In warm weather high temperature can be avoided by starting the fumigation in the late afternoon and continuing into the evening. The less resistant species of plants should be fumigated only on cloudy days or at night.

Although the effectiveness of naphthalene fumigation increases as the temperature increases, the recrystallization of the fumes at about 72° F., and the undesirable effect on the plants at 95° F. or higher, limit the temperature range between these points. In commercial fumigations a nearly constant temperature between 75° and 85° F. is practical and effective.

High relative humidities are unfavorable to red spider development and in a series of experiments in which no fumigant was used 59 percent of the red spiders were dead after three 6-hour exposures at 90 percent relative humidity compared to a 35 percent mortality after a similar exposure at 60 percent relative humidity.

In experimental fumigations the treatment was significantly more effective at 80 and 90 percent relative humidity than at 60 and 70 percent relative humidity, especially when 1 ounce and 1½ ounces of naphthalene per 1,000 cubic feet were used. The greater effectiveness of naphthalene fumigation at the higher humidities was also evident from the consistently greater number of red spider larvae which hatched from eggs fumigated at the lower humidities. Relative humidities of 75 to 80 percent are most satisfactory during naphthalene fumigation.

Because of the promising results from the first experiments with naphthalene, several combinations of materials have been used to enlarge the scope of the treatment and to simplify the operation. Locally a mixture of 85 parts of naphthalene and 15 parts of paradichlorobenzene was effective but not significantly superior under experimental conditions. Mixtures of naphthalene and nicotine were compatible and the residues from sulfur and Bordeaux mixture were not harmful on fumigated plants. Other investigators used solutions of naphthalene in sulfur and in motor oil very effectively in special apparatus. Two commercial liquid fumigants containing chemicals similar to naphthalene and used in the same way appear to give very satisfactory control of the red spider, and can be used safely at temperatures lower than are safe with naphthalene alone.

Greenhouse thrips and onion thrips are readily killed by naphthalene fumigation. The most common species of aphids and the adults of the greenhouse white fly are also killed but not as effectively as with nicotine fumes or hydrocyanic acid gas. Mealybugs are only partially controlled. Cyclamen mite is quite resistant to naphthalene fumigation, but the broad mite, a closely related species, is well controlled. Bulb mites and soil inhabiting pests are killed when exposed but because of their habits are seldom controlled. Leaf roller and leaf tyer moths are killed by strong fumigations but the larvae are more resistant.

Naphthalene fumigation may cause injury to plants if certain precautions are not observed, the usual causes being (1) fumigation of intolerant species, (2) failure to provide and maintain favorable atmospheric conditions, and (3) improper adjustment of the vaporizing apparatus. Melted naphthalene should never be allowed to boil nor to closely approach boiling in the vaporizing stove since the fumes given off under these conditions are injurious to plants. The recrystallization of naphthalene vapor from supersaturation or exposure to temperature below 72° F. may also injure plants. After the exposure of the fumigation is completed, the air should be gradually changed without lowering the temperature too rapidly.

Plant injury following improper naphthalene fumigation usually appears as white areas of dead but not diseased plant tissue, as yellow leaves which soon drop, and as bleached or faded areas on the petals of colored flowers.

Among the most common greenhouse crops, begonia (Chatelaine type), Boston fern, carnation, and cyclamen are very tolerant; while geranium, lilies, rambler rose, and tomato are usually injured. Most other species and varieties are near the border line between safety and injury and should be fumigated only when pest injury is severe and favorable conditions can be maintained. Greenhouses containing both tolerant and susceptible species of plants should not be fumigated unless the susceptible species are removed.

Fumigation with naphthalene or similar commercial preparations is a universal treatment for carnations in New England. In experimental plantings naphthalene fumigated carnations produced 14 to 21 percent more marketable flowers per plant than those receiving regular syringing with water.

Hybrid tea type of roses can be safely fumigated under the most favorable conditions, but the rambler and polyantha type are invariably injured.

Certain varieties of chrysanthemums are blinded by naphthalene fumigation during the bud forming period but are tolerant to this treatment at other times.

Cucumber and tomato fruits absorb and retain the odor and taste of naphthalene for several days after fumigation, making them objectionable to people with a sensitive taste. The tendrils and pistillate flowers of cucumbers may also be injured, and marginal burn on the leaves of both cucumbers and tomatoes occasionally results.

The initial cost for equipment to fumigate a 60,000 cubic foot greenhouse may vary from $25.25 if the fumigating stoves are purchased to $4.50 if they are homemade. The operating cost including fuel for raising the temperature in cold weather may vary from $5.49 to $1.84 for each treatment depending on the conditions.

LITERATURE CITED

1. Back, E. A. Carpet beetles and their control. U. S. Dept. Agr. Farmers' Bull. 1346, 13 p., illus. 1923.
2. ——— Clothes moths and their control. U. S. Dept. Agr. Farmers' Bull. 1353, 29 p., illus. 1923.
3. Bishopp, F. C. Fleas and their control. U. S. Dept. Agr. Farmers' Bull. 897, 2d revision, 15 p., illus. 1921.

4. Bourcart, E. Insecticides, fungicides, and weed killers. Translated from the French, revised and adapted to British standards by Donald Grant. 431 p., illus. London: Scott, Greenwood & Son. 1913.
5. Glasgow, H. The present status of carrot rust fly control in New York. Jour. Econ. Ent. 24: 189–196. 1931.
6. Hartzell, A. Naphthalene fumigation of greenhouses. Jour. Econ. Ent. 19: 780–786, illus. 1926.
7. ——— Tolerance of different species and varieties of plants to naphthalene vapor. Jour. Econ. Ent. 22: 354–360, illus. 1929.
8. ——— and Wilcoxon, F. Naphthalene fumigation at controlled concentrations. Jour. Econ. Ent. 23: 608–618, illus. 1930.
9. Maughan, F. B. Naphthalene for the control of the onion thrips. Jour. Econ. Ent. 26: 143–147. 1933.
10. Parker, T. The control of red spider. Hort. Trade Jour. 29 (No. 39): 27–28; 29 (No. 40): 27–28, illus. 1925.
11. Pettit, R. H. A repellent for flatheaded borers. Jour. Econ. Ent. 16: 97–98. 1923.
12. Read, W. H. Red spider investigations. (c) Fumigation. Expt. and Research Sta., Cheshunt, Herts, Ann. Rpt. (1927) 13: 69–75. 1928.
13. Roark, R. C., and Nelson, O. A. Maximum weights of various fumigants which can exist in vapor form in a 1,000 cubic foot fumigating chamber. Jour. Econ. Ent. 22: 381–387. 1929.
14. Searls, E. M. A simple method for life-history studies of root-feeding arthropods. Jour. Agr. Research 36: 639–645, illus. 1928.
15. Snapp, O. I. A new method of controlling the peach borer. *Synanthedon exitiosa* Say., with special application to young trees. Jour. Econ. Ent. 25: 786–799. 1932.
16. Speyer, E. R. Entomological investigations. Expt. and Research Sta., Cheshunt, Herts, Ann. Rpt. (1923) 9: 69–81. 1924.
17. ——— Entomological investigations. Expt. and Research Sta., Cheshunt, Herts, Ann. Rpt. (1924) 10: 82–104. 1925.
18. Smith, F. F. The cyclamen mite and the broad mite and their control. U. S. Dept. Agr. Circ. 301, 14 p., illus. 1933.
19. United States Department of Agriculture. Plant Quarantine and Control Administration. Japanese Beetle Quarantine 48 (P.Q.C.A. 224): 62–77. 1929.
20. Weigel, C. A., Smith, F. F., and Richardson, H. H. The gladiolus thrips. Florists' Exchange 79 (No. 11): 11, 40, 80B. 1932.
21. Wilcoxon, F., Hartzell, A., and Youden, W. J. Greenhouse fumigations with naphthalene solutions. Contrib. Boyce Thompson Inst. 5 (No. 4): 461–469. 1933.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
4m — 1-'36. No. 6598

3
327

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 327 FEBRUARY 1936

Annual Report

For the Fiscal Year Ending November 30, 1935

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Trustee Committee on Experiment Station

	Term Expires
BUTTRICK, DAVID H., Arlington, *Chairman*	1939
RUSSELL, HOWARD S., Waltham	1936
FROST, HAROLD L., Arlington	1938
MALCOLM, DAVID J., Charlemont	1939
WHITMORE, PHILIP F., Sunderland	1941
CHANDLER, JOHN, Sterling Junction	1942

Experiment Station Staff, December, 1935

HUGH P. BAKER, President of the College

SIEVERS, FRED J., Director
GASKILL, EDWIN F., Assistant to the Director
KENNEY, FRED C., Treasurer
CHURCH, LUCIA G., Secretary

*Bourne, Arthur I., Entomology
*Bradley, Leon A., Bacteriology
*Cance, Alexander E., Economics
*Chenoweth, Walter W., Horticultural Manufactures
Doran, William L., Botany
*Eisenmenger, Walter S., Agronomy
Fellers, Carl R., Horticultural Manufactures
*Frandsen, Julius H., Dairy Industry
†*Franklin, Henry J., Cranberries
*Gaskill, Edwin F., Station Service
Gibbs, Charles S., Veterinary Science
*Graham, John C., Poultry Husbandry
*Gunness, Christian I., Agricultural Engineering and Meteorology
*Haskins, Henri D., Fertilizer Law
Hays, Frank A., Poultry Husbandry
Holland, Edward B., Chemistry
‡*Koon, Ray M., Horticulture
*Lentz, John B., Veterinary Science
*Lindsey, Adrian H., Agricultural Economics and Farm Management
Lindsey, Joseph B., Chemistry (Professor Emeritus)
*Mitchell, Helen S., Home Economics
*Osmun, A. Vincent, Botany
*Rice, Victor A., Animal Husbandry
*Ritchie, Walter S., Chemistry
*Sears, Fred C., Pomology
Shaw, Jacob K., Pomology
*Smith, Philip H., Feed, Dairy and Seed Laws
*Thayer, Clark L., Floriculture
Van Meter, Ralph A., Pomology
Van Roekel, Henry, Veterinary Science
‡Whitcomb, Warren D., Entomology
*Wood, Basil B., Library

Archibald, John G., Animal Husbandry
Bailey, John S., Pomology
§Bergman, Herbert F., Cranberries
Brown, Alfred A., Agricultural Economics and Farm Management
Bullis, Kenneth I., Veterinary Science
Creek, Charles R., Agricultural Economics and Farm Management
DeRose, H. Robert, Fertilizer Law
‡Dempsey, Paul W., Horticulture
*Felton, F. Ethel, Editor
Flint, Oliver S., Veterinary Science
France, Ralph L., Bacteriology
Fuller, James E., Bacteriology
‡Graves, George, Nursery Culture
‡Guba, Emil F., Botany
Jones, Carlton P., Chemistry
Jones, Linus H., Botany
§Kightlinger, Clifford V., Tobacco-Disease Investigations
Kuzmeski, John W., Fertilizer Law
McKenzie, Malcolm A., Botany
McLaughlin, Frederick A., Seed Law
Mighell, Ronald L., Agricultural Economics and Farm Management
Mueller, William S., Dairy Industry
Rozman, David, Economics
Spelman, Albert F., Feed Law
‡White, Harold E., Floriculture
‡Young, Robert E., Vegetable Gardening

Allen, Harry L., Feed, Fertilizer and Dairy Laws
Ball, Alyn S., Botany
Bean, Donald A., Horticultural Manufactures
Becker, William B., Entomology
Bennett, Emmett, Chemistry
Cary, Marjorie, Agricultural Economics and Farm Management
Clague, John A., Horticultural Manufactures
Clarke, Miriam K., Veterinary Science
Cook, Gladys, Home Economics
Donley, J. Elizabeth, Agricultural Economics and Farm Management
‡Donnelly, Edward B., Floriculture
Esselen, William B., Jr., Horticultural Manufactures
‡Gilgut, Constantine J., Nursery Culture
Hoefle, Olive M., Seed Law
Howard, James T., Feed, Fertilizer and Dairy Laws
Hughes, Mary C., Pomology
Levine, Arthur, Horticultural Manufactures
Maclinn, Walter A., Horticultural Manufactures
Merriam, Oreana A., Home Economics
Miner, Gladys I., Botany
Murray, Robert V., Horticultural Manufactures
O'Donnell, Margaret H., Administration
Parkinson, Leonard R., Station Service
Sanborn, Ruby, Poultry Husbandry
Sherburne, Ruth E., Economics
Smith, William T., Agricultural Economics and Farm Management
Snell, Moses E., Agronomy
Southwick, Lawrence, Pomology
Taylor, Marion, Horticultural Manufactures
§Truran, Walton E., Cranberries
‡Wilson, Harold A., Vegetable Gardening
Yegian, Hrant M., Agronomy
Zimnoski, Felicia, Veterinary Science

*In charge †At East Wareham ‡At Waltham §With U. S. D. A.

CONTENTS

PAGE

Introduction 4

Department Reports:

Agricultural Economics and Farm Management 5

Agricultural Engineering 8

Agronomy 9

Animal Husbandry 16

Bacteriology 19

Botany 23

Chemistry 28

The Cranberry Station 30

Dairy Industry 35

Economics 37

Entomology 39

Feed Control Service 54

Fertilizer Control Service 55

Floriculture 57

Home Economics 59

Horticultural Manufactures 60

Olericulture 64

Pomology 68

Poultry Husbandry 73

Veterinary Science 74

Waltham Field Station 78

Cooperative Investigations:

Cranberry 33

Tobacco 13

Publications 80

ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION — 1935

INTRODUCTION

F. J. Sievers, Director

In our attempts to deal with the problems of agriculture through experiment station services it has become recognized that the best interests of the individual operator quite commonly come into conflict with what is economically most sound for the industry. While the industry in its entirety reacts definitely to certain causes and effects, the individual units that compose the industry are not always so influenced. It is mainly for this reason that many of the attempts to regulate the operations of, or to prescribe for, the entire industry have not been received with sufficient enthusiasm by enough individuals to make them successful.

In the experiment station a realization of this fundamental principle has made the investigator so conservative that he has hesitated to project the results from his investigations beyond what could be supported by definite data obtained through an analytical approach. When urged to go beyond this, he has in some cases been willing to make recommendations for individual farms if he felt thoroughly conversant with the detailed operations, but then only with a realization that his recommendations would not prove sound for the entire industry. While such service may have been relatively satisfactory when agriculture was reasonably profitable, it is not considered adequate when an industry is in economic distress.

There has been a feeling on the part of a large number of constructive statesmen that agriculture, in proportion to the prominent position it occupied in the Nation's business, was not getting its fair share of the financial return. The industry needed and deserved help. It needed the type of help that the experiment stations could give if they expanded their field of operations beyond applied science and into the province of applied economics. Support for this type of development was provided by increased Federal as well as State funds, and researchers trained in the specialized field of economics and farm management were added to the staff. Such supplementary service was intended to extend the influence of agricultural research beyond the horizon set by the applied scientist. This was a laudable objective and one that was accepted with enthusiasm but unfortunately with a decidedly limited background of experience.

Economics was called the "dismal science" because it had been content to confine itself largely to the past. The agricultural chemist had learned that, to meet present-day demands, it was not enough to be familiar only with the ideals and accomplishments of such pioneers as Justus von Liebig; while the economist was still quite content to quote from Adam Smith. The science of economics had been concerned only with looking backward, and suddenly it was assigned the problem of prescribing for the present and also for the future. This necessitated the development of new methods and new viewpoints but under already-established administrations. It was only natural, therefore, that the methods of research that had proved effective in the field of applied science should be introduced here, namely, the analytical approach. Several years of relatively fruitless effort with this method, which accomplished little besides the amassing of mounds of data of a census nature, made it very evident to some that research in the field of economics must vary its program if it was to overcome the limitations that were rapidly becoming recognized. The greatest need was not for more unrelated facts or data, but for the finding of a relationship between those already available or within easy reach. This led to an attempt at correlation which required a type of cooperation with subject-matter departments that heretofore had never been considered necessary.

This incentive for cooperation has been, and can be to a much greater extent, the most significant contribution of the economist to agricultural research. So long as economists operate independently and restrict their services to the confines of economics as laid down by departmental boundaries, their efforts will be of very limited significance in serving the agricultural industry. The public is demanding that our researchers project their results beyond what is justified by statistical data only. The specialist in applied science will do this to the degree that he is willing to develop the courage to express an opinion. His opinions will be respected as far as they are found reliable. If the economist can encourage him to venture further into this field and then cooperate with him in making sure that his venture is on a sound basis, he will contribute much of the service that is demanded of him. It is believed that then and then only shall we get sound and constructive service in planning for the economic future in agriculture. Progress in this direction is being made. It is limited only by the extent to which the economist is capable of realizing that this may be his most worth-while service, and the scientist of recognizing that the results from his research may require an economic interpretation that he, independently, may not be qualified to supply.

Administratively every effort is being made to promote and develop relationships which will encourage this enlargement in our service. It is hoped, now that funds from Bankhead-Jones sources are available, that added flexibility may be injected into our program thus making the plan more quickly and more generally operative.

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

Farm Tax Delinquency and Farm Real Estate Values. (R. L. Mighell.) This study was carried on in cooperation with a Civil Works project administered by the Federal Bureau of Agricultural Economics. The records were gathered in 1934 and the analysis completed during this year. A mimeographed statement, entitled "Tax Delinquency of Rural Real Estate in 37 Massachusetts Towns, 1928–33," released September 19, 1935, by the Bureau of Agricultural Economics, summarizes the results to date.

As found in this study, rural real estate tax delinquency on the 1932 levies in 37 Massachusetts towns involved more than 201,000 acres, an increase of 34 percent over the acreage delinquent on the 1928 levies. During the same period the amount of taxes delinquent increased 70 percent. Not only did delinquent acreage increase, but delinquency per acre also increased. At the end of 1932 the period of delinquency for all properties then involved averaged 1.5 years. Other information available indicates that much of the delinquency in this State represents merely a slowness of payment.

During the five years 1928–32, tax certificates or tax liens were sold against a very minor part of the delinquent acreage. By the end of 1931 about one-third of the acreage delinquent on the 1928 and later levies had been cleared.

The delinquent area in 1928 equaled 63 percent of the area in farms in the 37 towns. The corresponding figure for 1932 was 85 percent. In the towns here included is located 12 percent of the farm area of the State. The comparison with area in farms is probably more significant than a comparison with total area as most of the delinquency reported was on farm land. The area delinquent in the 37 towns in 1932 was reported by types as follows: 70 percent in farms, 13 percent in forest, and 17 percent in miscellaneous types or not classified.

For the five-year period, 15 percent of the properties sold were later redeemed. The proportion redeemed from each year's sales decreased from 39 percent in 1928 to 8 percent in 1932. None of the properties sold to private buyers in 1931 and 1932 were reported as redeemed.

The situation indicates a substantial increase in rural tax delinquency. It is apparent, however, that only a minor part of such delinquency led to dispossession of title or even to the sale of tax certificates against the property. In many cases the taxes are paid soon after becoming delinquent, and many of the remaining delinquencies are allowed to continue without further action on the assumption that they will be paid.

On the other hand, many of the properties appear to have been delinquent on no more than one levy at a time. This delinquency was largely "short-term," but chronic. It was short-term in the sense that few of these owners let any individual levy remain delinquent for more than a year or two, but it was chronic in the sense that the properties became delinquent year after year, on successive levies. The most typical case from among these would be one of a property going delinquent repeatedly, but on which each delinquency was paid before the following levy became delinquent. Furthermore, the number of tax sales indicates that in relatively few cases was procedure started to dispossess the owner of title to the land.

Milk as a Municipal Utility. (R. L. Mighell.) The emergencies of the recent depression years have hastened the growth of the belief that there is a public interest in the distribution of milk. For example, the opening section of the Massachusetts Milk Control Law of 1934 states that milk production and distribution is a business with "a paramount public interest." Many people are even ready to say that the providing of milk is as much of a public utility as the providing of water, electricity, and transportation, and that regulation and possibly public control and ownership are close at hand.

This project was initiated to determine whether handling milk distribution as a municipal utility in a particular municipal market is economically and socially desirable, and if possible to throw some light on the extent and type of public control or operation which would be most sound.

As yet there has been little public experience with any business similar to the milk industry. As contrasted with other public utilities the following peculiarities may be noted:

1. Threefold division of the industry between producers, transporters, and distributors.
2. Large numbers of producers and distributors as compared with one or two firms in the usual public utility.
3. Difficulties of fixing rates with many enterprises of different types handling milk.

4. Enforcement problems which are not involved in present utilities.

5. Cost determinations more unsatisfactory than in the case of present utilities.

In view of these difficulties, the first step in the prosecution of the study was to learn as much as possible about the few existing cases in which some measure of public utility operation has been undertaken. Perhaps the most outstanding instance of municipal control of the milk supply is found in the city of Wellington, New Zealand. Legislative authority for taking control of the milk business was obtained as early as the year 1910, but it was not until the time of the World War, when the milk situation became extremely acute, that the corporation of the city of Wellington resolved to enter upon a comprehensive scheme to distribute milk in Wellington and its suburbs. After several preliminary attempts the city commenced to purchase milk from farmers and process and distribute it in January 1919. At the present time the municipality owns all of the physical equipment necessary for purchasing, processing, and distributing the major portion of the milk supply to the residents of the city. There is not a complete monopoly on the part of the municipal organization since local producers and distributors are permitted to continue in business under strict regulation, and in the course of time their numbers and the volume of milk so handled have increased to some extent. Nevertheless the municipality controls the bulk of the milk supply and has apparently been extremely successful in handling the situation.

In the United States there are a few isolated instances of close municipal control and ownership of physical facilities. One small town in North Carolina has a complete monopoly of milk distribution. The two former independent distributors, who happened to be also the mayor and the chief of police, finding themselves in financial difficulties arranged to sell out to the city, and the business is now being conducted as a municipal enterprise with apparent success.

In another instance, a few years ago several adjoining towns in New Jersey purchased pasteurization equipment in common. They control the situation by means of a system under which the town purchases all milk from the farmers, processes and bottles it, and then sells to distributors who handle their business in other respects in the same ways as formerly.

In a few fairly large markets in the United States there is a limited number of distributing agencies in the business. It is possible that a close study of the situations in which one or a very few distributors handle most of the business will aid in leading to conclusions about the possible savings which can be made under municipal control. It is highly probable that the economies which can be realized by eliminating some of the most apparent inefficiencies of multiple distribution are not as great as people think.

The study up to date has been confined to an analysis of what has happened in these existing situations. Later it is proposed to select a single secondary market in Massachusetts as a case for detailed study to determine the advantages and disadvantages of municipal control, operation, or ownership of all or part of the milk distribution facilities under the conditions peculiar to that market.

A Study of Adjustments in Farming by Regions and Type-of-Farming Areas, from the Standpoint of Agricultural Adjustment and Planning, Including Soil Conservation. (Jointly with the Department of Economics. David Rozman and R. L. Mighell.) The results of this project are reported in full elsewhere (see report of the Department of Economics.) The study is being further refined and continued primarily by the Extension staff in Agricultural Economics as a part of the county agricultural program planning project. Under this program farmer committees are cooperating with the county and state agricultural extension services in thinking through farm problems and developing local plans of action.

Background data on national, regional, and local acreages and production, trends of crops and livestock, trends in population changes, in numbers and sizes of farms, and the like are being organized and placed in available form for use of these local committees and farmers. The first-hand knowledge of these local people is indispensable for the development of systems of farming which will conserve soil resources, maintain soil fertility, and result in adequate farm incomes and farm living. The continuing lines of economic research of the agricultural experiment station and the United States Department of Agriculture will be coordinated with the development of the programs. Judgments of local farmers concerning the effects of proposed farming systems, marketing plans, price policies, and other agricultural adjustments are needed in arriving at sound judgments just as much as local farmers need assistance from Federal and State agencies. The organization of the continuing phases of this project will be mutually beneficial.

DEPARTMENT OF AGRICULTURAL ENGINEERING

C. I. Gunness in Charge

Investigation of Apple Storages. (C. I. Gunness in cooperation with the Department of Pomology.) A study was made of the rate of cooling of apples in large blocks of bushel boxes in various storages. The season was not favorable for this study due to cool weather at the time of harvest. The study did reveal, however, that apples are cooled more rapidly and with greater uniformity throughout the room when diffusers or blowers are used than when wall and ceiling coils are used. There was practically no difference in rate of cooling in boxes at different heights in the stack in rooms cooled by blowers. In rooms cooled by coils, there was a great difference in the rate of cooling at different levels. With this system, the air cooled by the coils drops to the floor and circulates among the bottom boxes, cooling the apples rapidly. As the air is warmed, it rises to the top with the result that the top boxes are cooled very much more slowly. The blowers maintain a high air velocity through the room with correspondingly small temperature variations, hence the cooling is more uniform.

The relative humidity conditions in storages have been studied, particularly in connection with ventilation at times when the outside temperature is lower than the storage temperature. While the relative humidity may drop from 95 percent to 80 percent during the time of ventilation, the original humidity is re-established a very short time after the blowers are shut off. The experience of growers substantiates the assumption that the lowering of the humidity for short intervals of time creates no appreciable shrivelling. The variation in humidity from this cause is only slightly greater than that produced by the starting and stopping of the blowers when the air is recirculated over the refrigerated pipe coils.

Low-lift Pumps for Cranberry Bogs. (C. I. Gunness.) Last year we reported on the construction of a plant for testing low-lift pumps. Additions have been made to this plant during the past year, and it is now in working condition. The purpose of this project is to improve the performance of pumps such as are now in use on cranberry bogs. Two pumps have been built and tested, but the work has not progressed far enough to warrant a report at this time.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Pasture Experiments. (W. S. Eisenmenger.) Pasture plots in Hampshire and Worcester counties were given different fertilizer treatments. Some received a "complete fertilizer"; others were given applications of a single material supplying nitrogen, phosphorus, or potash. Pasture grasses responded best to the more complete fertilizer. During the early part of last season when abundant rainfall occurred, potash seemed to induce a good stand of white clover. During several seasons nitrogen increased growth more frequently than any other single fertilizer material. The soils were all of the Gloucester type, and therefore a fertilizer treatment was not fully effective unless it included lime.

Tobacco Projects. (W. S. Eisenmenger and M. E. Snell.)
Cropping Systems. The tobacco experiments reported in 1934 have been continued during the past year with some modifications. The pH of the soil was approximately 5. In order to eliminate as far as possible the effects of black root-rot (*Thielavia basicola*), strains resistant to this disease were chosen instead of the ordinary strain of Havana which had been used previously. The following are the yields resulting from different treatments under the same conditions of fertilization:

Check plots without lime	2249
Check plots with lime	2053
Red top cover crop	2243
Italian rye grass cover crop	2140
Orchard grass cover crop	2175
Tall meadow oat grass cover crop	2084
Spinach cover crop	2079
Manure, no cover crop	2275
Manure and red top cover crop	2079
Manure and red top hay	2384
After red top hay	1945
After red top and clover hay	2497
After timothy hay	2143
After timothy and clover hay	1898
After potatoes	2303
Corn stover applied	2312
Third year tobacco plots	2330

Methods of Applying Fertilizer. This is a continuation of the experiment started in 1932 to compare the relative effectiveness of fertilizers for tobacco when broadcast and when placed in the row. The following yields were obtained:

Row Application	Pounds per Acre	*Broadcast Application (Check)*	Pounds per Acres
¾ Standard amount	1874	Standard amount	2128
⅝ Standard amount	1708	Standard amount	1994
½ Standard amount	1743	Standard amount	2086

During the years 1932 and 1933 the relative yields of tobacco were better when the fertilizer was placed in the row than when it was broadcast. Approximately ⅝ the amount, when applied in the row, was equivalent to the full amount broadcast. However, during the last two years, 1934 and 1935, the favorable effect of row application has not continued. It seems that the residual effects of fertilizer applied broadcast in previous years has overcome this seeming advantage.

Proportion of Organic Nitrogen. Varying amounts of cottonseed meal as a source of nitrogen for tobacco were used in field trials and the relative yields were as follows:

	Pounds per Acre
Check (regular tobacco mixture)	2330
⅛ N from cottonseed meal	2291
¼ N from cottonseed meal	2152
⅜ N from cottonseed meal	2193
½ N from cottonseed meal	2221

Form of Nitrogen. This experiment was planned to determine which form of nitrogen is most valuable from the standpoint not only of yield but of the production of good quality in tobacco. One half of the nitrogen was supplied from cottonseed meal and the other half from the following materials. The yields show no marked differences.

	Pounds per Acre
Check (regular tobacco mixture)	1910
½ N from nitrate of soda	1967
½ N from sulfate of ammonia	1925
½ N from calcium cyanamid	1859
½ N from urea	1895

Distribution of Nitrogen in Soils Mixed with Different Plant Tissues and Allowed to React for Two Months. (W. S. Eisenmenger.) Tobacco planted in rotation with corn or timothy is frequently affected by brown rootrot during certain seasons. Experiments at other stations show favorable results when tobacco follows ragweed, horseweed, or tobacco. An attempt was made in the laboratory to learn whether the manner in which these various tissues break down would show any reason for the effect which they produce on tobacco.

Ground tissue from each of the plants — tobacco, horseweed, ragweed, timothy, red top, and corn — was mixed with soil in crocks, in amounts to keep the nitrogen equal. At the end of eight weeks those soils containing vegetative tissues of red top, timothy, and corn contained more carbon than did the soils containing tissues from tobacco, ragweed, and horseweed.

It has been the experience in our laboratory that those plant tissues which are slow in losing carbon when mixed with soil are also slow in ammonifying and nitrifying.

Different forms of nitrogen from each of these mixtures are now being determined; namely, total nitrogen, ammonia, amino acid, amides, nitrate, and humin nitrogen.

The Absorption by Food Plants of Chemical Elements Important in Human Nutrition. (W. S. Eisenmenger and E. B. Holland.) It has been found desirable to know to what degree the relative abundance of an element in soils influences the intake of that element into the plant. Individual soil plots were treated with basic copper sulfate, manganese dioxide, iron oxide, and potassium iodide.

Preliminary studies would seem to indicate that the rate of intake of elements is not always proportionate to the amounts of the elements present. Evidence from this experiment would lead us to believe that the reaction of ions from salts does not function in the plant membrane as it does under conditions where the mass action law is applicable. However, iodides do seem to be taken up much more readily when the salts of this element are more abundant in the soil. The intake of iron through a plant membrane is probably regulated to a considerable degree by the hydrogen-ion concentration of the medium.

Magnesium Requirements of Plants. (W. S. Eisenmenger and M. E. Snell.) During 1934, the depressing effects of magnesium deficiency were shown in a potato field on a farm about five miles from Amherst (Petrosky farm). The college conducted experiments on this field in 1935, with oats, potatoes, and corn. During the early period of the growing season when there was abundant rainfall, the crops showed definitely the effects of low magnesium. As the season progressed and the moisture supply became limited, the results were less apparent. The yields were inconclusive.

Onion Set Production. (M. E. Snell.) Owing to the early appearance of the onion "blast" the past season, the sets stopped growing before many of them reached the desired size for planting. This prevented getting much additional information on the time of pulling the sets as a means of controlling size. Very good stands were procured in every case from the four plantings made at weekly intervals, and the early growth was excellent. The "blast" appeared first and seemed to be most severe on the plots where rows were eleven inches apart and on the two late plantings. The early plantings, where the plants were older and tougher from having grown more slowly, and where the rows were wider apart giving better circulation of air, were least affected.

Onion Breeding. (M. E. Snell.) Unusually good results were obtained the past season on this project. Seed production was better than in previous years both with the inbred strains and with a number of selections which were planted for massed crossing. Some of these were selections from previous crosses and some from inbred strains only. The bulbs grown directly from seed sown in the field were in most cases good, and those grown from transplants and sets were again very satisfactory. A number of very good lots of small sets for planting next year were also grown from inbred seed. A selection of Sweet Spanish onions grown from seed on a nearby farm a year ago, was planted for seed production. A fair amount of seed was procured from some of the bulbs.

Experimentation with Artificial Manure. (W. S. Eisenmenger and K. Kucinski.) During the past year, large quantities of different types of artificial manures were prepared in order to study their chemical composition and fertilizing values.

Chopped corn stover, mixed deciduous tree leaves, and oat straw were used as the sources of organic material. "Aero" Cyanamid was the nitrogenous supplement used in aiding the decomposition of the organic matter. For comparison, similar manures were made using sulfate of ammonia. Interesting information was obtained in regard to the rapidity of the decaying process, the heat and moisture relationship, and the volume and appearance of the finished product. It was found that the artificial manure made from leaves took the longest, and the manure made from corn stover the shortest, time to decompose into what was considered a finished product. The chemical analysis of the artificial manures compared favorably with "natural" manure.

The fertilizing value of the different types of manures was determined in both pot and field experiments. In the pot experiments, barley showed greatest yields with heaviest applications of the artificial manure. In the series where artificial manures were used at the rate of 30 tons per acre, the manure made with cyanamid showed slight signs of toxicity. The best growth of barley was obtained where an equivalent amount of commercial fertilizer was used.

Corn was grown in the field experiment, and "natural" horse manure was used as a check against the different types of artificial manures. The manures were applied at the rate of 10, 20, and 30 tons per acre. It was found that with the higher applications of the artificial manures the yields of corn were much greater than the yields where horse manure was used. In most cases the yields of corn grown on artificial manures made with cyanamid were at least as good as the yields of corn grown on artificial manure made with sulfate of ammonia.

Further chemical analyses will have to be made before the project is completed.

Hay Seeding Mixtures. (W. S. Eisenmenger, R. W. Donaldson, E. F. Gaskill.) Thirteen mixtures of alfalfa, red clover, timothy, orchard grass, and red top in varying amounts and combinations, were seeded in August 1935 in three series. In series I, the rate of seedings was 21 pounds per acre with three replications. In series II, seedings were at the rate of 17 pounds, in duplicate. In series III, seedings were at the rate of 13 pounds in duplicate. It is planned to obtain data on botanical composition and yields beginning in 1936.

Alfalfa Variety Tests. (W. S. Eisenmenger and M. E. Snell.) Twenty-one varieties of alfalfa have been sown during the past year. It is too early to tell which strains are most suitable to this area.

Testing Varieties of Corn for Grain. (R. W. Donaldson, W. S. Eisenmenger, M. E. Snell, and J. Everson.) As a result of increased interest on the part of farmers in the State in growing some corn for grain, a test of 66 varieties was made during 1935, in an attempt to obtain information as to varieties to be recommended for this purpose. Yield data of total fodder and of grain were obtained, as well as information on maturity for one season. Additional tests of 17 varieties were conducted at the county agricultural schools in Bristol, Norfolk and Essex Counties.

Potato Variety Tests. (R. W. Donaldson, W. S. Eisenmenger, A. I. Bourne, and E. F. Gaskill.) Certified seed obtained from Maine, Michigan, and New York and grown on the college farm in 1935, gave the following yields: Chippewa (Maine) 542 bushels per acre, Green Mountain (Maine) 440 bushels, Katahdin (Maine) 423 bushels, Russet Rural (New York) 384 bushels, Warba (Michigan) 343, Golden (Maine) 280 bushels. The same comparative order in yields was obtained on a farm in Sunderland.

Fine Turf Grasses. (L. S. Dickinson.) All the fine-turf plots have been abandoned and either plowed under or transferred to a regularly used putting green where observations are being made as to the behavior of certain varieties of bent grass under actual playing conditions.

One project has been completed; To determine "the effectiveness of a certain proprietary weedicide in controlling the chickweeds (*Stellaria media* and *Cerastium vulgatum*) in fine turf." It was found that the weedicide was effective in a concentration of 1–100 applied at the rate of one gallon per 1,250 square feet. The grass was injured but recovered within reasonable time.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in Cooperation with the Massachusetts Agricultural Experiment Station.

C. V. Kightlinger, U.S.D.A., in Charge

Black Root-Rot. (C. V. Kightlinger.) Fifteen strains of Havana Seed tobacco were tested comparatively in the field in 1934 (the fifth year of the investigation) in continuation of the attempt to find strains which may be satisfactory under Connecticut Valley conditions for resistance to black root-rot and for type of plant, type and quality of leaf, gross producing capacity, and such other properties as may be necessary in order that the strains may be acceptable to producers and to manufacturers.

Two strains of Havana Seed tobacco which possess between them, in acceptable degrees, those characteristics which the new strains must possess in equal or greater degrees in order to fulfill the objectives of the investigation were grown for control purposes. One strain was Havana Seed of the sort that is grown most commonly at present in the Connecticut Valley. When grown under favorable conditions this strain is ordinarily acceptable for type of plant, type and quality of leaf, and gross producing capacity. The tobacco produced by this strain under favorable conditions is acceptable in general for the commercial uses made of Havana Seed tobacco. However, like all other strains of common Havana Seed tobacco, this strain is sufficiently susceptible to black root-rot to make it unsatisfactory in most cases when grown under black root-rot promoting conditions. The other strain was Havana Seed 142A3. This strain, although not immune, is highly resistant to black root-rot, and ordinarily is acceptable for gross producing capacity under conditions which are favorable to the development of the disease. It produces even more heavily under black root-rot free conditions. Unfortunately this strain is not entirely acceptable for type of plant or for type and quality of leaf, even when grown under favorable conditions. The tobacco produced by this strain is not acceptable in most cases to dealers and to manufacturers.

The fifteen strains tested in 1934 consisted of several which had been previously used, together with certain others grown for the first time in 1934. The older strains had been found to possess desirable characteristics in considerable degree and had been retained for further testing to more fully determine their value. These fifteen strains consisted of one which had been grown for the first time in 1930, four in 1931, five in 1932, three in 1933, and two which were grown for the first time.

All of the strains and the controls were grown in small plot experiments: in one case on land which was relatively free of black root-rot promoting conditions, and in the other case on black root-rot land. The controls were grown at sufficiently frequent intervals throughout the experimental areas to provide adequate checking of results. The land used in each case was well suited to the purposes of the experiments, and good tests of the strains were obtained in all respects, except for resistance to black root-rot. Due to certain weather conditions which were unfavorable to a severe development of black root-rot the resistance of the strains to the disease was not subjected to a rigid test, as was indicated by the limited amount of black root-rot which developed on the common Havana Seed control.

Several of the strains tested in 1934 rated high according to the standards employed. Some of these strains, however, had been tested for so short a time that their characteristics and their worth were insufficiently known. Others had been tested throughout all or a considerable part of the investigation, and rated high each year in comparison with the controls. Of the latter, the most important were Strains 13 and 29. Strain 13 and the controls had been grown on root-rot free land for five consecutive years, and on infested land for four consecutive years, including 1934. Strain 29 had been grown on disease-free land for two years, and on diseased land for three years, including 1934. These tests demonstrated that the two strains possessed essential characteristics in high degree, and possibly to the extent of fulfilling the objectives of the investigation. Practical testing of Strain 13 in 1934 on approximately thirty-five acres of land in cooperation with nine growers in numerous places in the Connecticut Valley tended to confirm this conclusion, at least in the case of Strain 13. It seemed that the greatest need in further work with these strains was larger scale testing on the one hand, to make sure that no characteristics of importance had been overlooked; and more extensive trials in cooperation with growers on the other hand, to determine how far these strains might be acceptable to producers and to leaf dealers and manufacturers. Accordingly, to complete the studies, these strains were grown in 1935 in well-organized and closely supervised experiments on the same amount of land which previously had been used for the small plot testing of all the strains, and the two strains alone were grown in practical tests in cooperation with good growers in various places in the Connecticut Valley. Strain 13 was grown in cooperaation with fourteen growers, and Strain 29 with nine growers, on areas which ranged from a portion of an acre to as much as fifteen acres per trial. Approximately seventy-five acres of Strain 13, and thirty-five acres of Strain 29, were grown. The results of the tests are not yet available.

The production data of Strains 13 and 29 and the controls for the periods of time indicated are as follows:

Strains	Grown on black root-rot free land				Grown on black root-rot land			
	Year of test	Average yield per acre (pounds)	Average grade index	Crop index	Year of test	Average yield per acre (pounds)	Average grade index	Crop index
I. For 1934								
Common strain	1934	2312	.407	941	1934	1565	.329	515
142A3	1934	2441	.456	1113	1934	1749	.370	647
13	1934	2395	.487	1166	1934	1876	.407	764
29	1934	2460	.449	1105	1934	1913	.405	775
***II. For the duration of tests of respective strains**								
Common strain	1930–34	2050	.417	855	1931–34	1328	.309	420
142A3	1930–34	2200	.451	992	1931–34	1872	.362	678
13	1930 34	2212	.476	1053	1931–34	1944	.407	791
29	1933–34	2420	.428	1036	1932–34	2068	.391	809
III. For identical periods of time								
Common strain	1933–34	2195	.401	880	1933–34	1455	.341	496
142A3	1933–34	2300	.436	1003	1933–34	1881	.377	709
13	1933–34	2299	.450	1035	1933–34	1925	.422	812
29	1933–34	2420	.428	1036	1933–34	2075	.417	865

*See explanation in text

Grade index, as used here, is a number expressing the grading quality of tobacco produced under the conditions of the experiment. It is based upon the percentage yield of each grade of tobacco and the relative values of these grades of tobacco, given below:

Lights	1.00	Long darks (19″ and longer)	.30
Mediums	.60	Dark stemming (17″ and shorter)	.20
Long seconds (19″ and longer)	.60	Fillers	.10
Short seconds (17″ and shorter)	.30	Brokes	.10

The grade index is derived by multiplying the percentage yield of each grade of tobacco by the respective rating of the grades, given above, and adding the products.

Crop index, as used here, is a number expressing the crop value of tobacco produced under the conditions of experiment. It is based upon the gross yields of tobacco per acre and the grade index of the tobacco.

The crop index is derived by multiplying the gross yield of tobacco in pounds per acre by the grade index of the same tobacco.

Grade index and crop index and the adopted relative values of the different grades of tobacco, as used here, do not necessarily represent current commercial values and prices of tobacco.

The average measurements and determinations of types of plants and leaves produced by Strain 13 and 29 and their controls in 1934, when grown on black root-rot free land, were as follows:

Strains	Height of plants topped high (inches)	Number of leaves per plant	Length of internodes (inches)	Length of leaves (inches)	Width of leaves (inches)	Diameter of stalks topped high	
						Butt (inches)	Top (inches)
Common strain	35.9	17.1	2.1	27.8	12.8	1.4	0.8
142A3	33.9	19.1	1.8	26.0	12.3	1.3	0.8
13	38.9	16.9	2.3	28.5	15.0	1.4	0.8
29	39.0	18.5	2.1	26.5	13.8	1.3	0.8

Additional data on the comparative shape of leaves of the different strains of tobacco grown in 1934, but not given here on account of their detailed nature, showed the average shape of leaves produced by Strains 13 and 29 under similar conditions to be approximately the same. The leaves produced by these strains were wider at mid-length in comparison to their entire length, than were the leaves produced by the common Havana Seed strain and Strain 142A3 under similar growing conditions, and they carried this proportionately greater width well toward their tips and toward their butts. Strain 13 produced somewhat larger leaves on the average than did Strain 29 and the controls.

Strain 13 proved to be very satisfactory in seven of nine practical tests made in 1934, and was considerably superior to common Havana Seed tobacco for yield and quality in some of these trials. In these seven tests, the producers approved the strain. The dealers who handled the tobacco pronounced it to be satisfactory for type and quality. The tobacco also sweat satisfactorily. Two of the nine practical tests of the strain made in 1934 were not entirely satisfactory, although in one of the tests Strain 13 was more satisfactory than the common Havana Seed tobacco grown in the trial for comparative purposes. In the other of these two trials no common Havana Seed tobacco was grown. Strain 29 was not grown in practical tests in 1934.

Strain 13 has proved to be sufficiently promising in small plot experiments performed during the course of the investigation and in practical tests in 1933 and 1934, to have justified the increased practical tests of the strain made in 1935. Strain 29 has proved to be sufficiently promising in small plot experiments for the duration of its tests, to have justified the practical tests made in 1935.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

The Proper Supplementary Ration for Milking Cows on Pasture. (J. G. Archibald, V. A. Rice, R. C. Foley, and C. H. Parsons.) This project was continued during the pasture season of 1935 along the same lines as in 1934. An article giving the results for both seasons has been accepted for publication in *Hoard's Dairyman* and will appear shortly. The results for 1935 confirm those reported in 1934 and lead to the conclusion that there is no apparent necessity for anything more than very limited grain feeding when pastures are good.

The Relative Efficiency for Milk Production of Proteins from Animals and Vegetable Sources. (J. G. Archibald, V. A. Rice, and C. H. Parsons.) The first phase of this project which involved a comparison of dry rendered tankage with a mixture of cottonseed and soybean meals was completed in April of this year and the results published in Bulletin 321, entitled "Tankage as a Source of Protein for Dairy Cows." The principal conclusion reached was that high grade tankage can be safely added to the list of protein feeds for dairy cows, provided the usual precautions for feeding protein concentrates are observed.

A second phase of the project is now in progress, twenty-two cows being utilized to determine the value of dried blood as a source of protein in comparison with the above-mentioned meals. The procedure being followed is identical with that reported last year. The trial will continue until the close of the barn feeding season late in April.

The Effect of Feeding a Vitamin A Concentrate on Reproduction in Cattle. (J. G. Archibald, V. A. Rice, and C. H. Parsons.) This project is being conducted in cooperation with the Chas. M. Cox Company of Boston and the National Oil Products Company of Harrison, N. J. Approximately two-thirds of the milking cows and all of the heifers one year old and over, in the college dairy herd, are being utilized in a long-time experiment on the problem. The vitamin concentrate is incorporated in the regular grain mixture at the rate of 5 pounds per ton. Detailed records are being kept of every phase of the reproductive life of all animals in the group and will be checked against past reproductive history of the herd. A group not receiving the vitamin concentrate but treated identically in other respects is serving as a control. As the experiment has been in progress only a few months results are not yet available.

Studies in the Chemistry of Pasture Grass. (J. G. Archibald and E. Bennett.) Results of three years' work on the composition of individual species of grass appeared in the *Journal of Agricultural Research* for April 15, 1935 (Vol. 50, No. 8), under the title, "Yield and Chemical Composition of Certain Species of Grass."

The grasses used in this study were grown without fertilizer other than that residual in the soil. The series of plots on which they were grown is now being utilized to study the effect of fertilizer on the several species. As noted last year the work has been seriously interfered with by winterkilling during the past two winters, which have been unusually severe. Results will not be available for at least another year.

A second series of plots has been established on a very different soil type, in order to ascertain what effect, if any, soil type has on the species in question. This phase of the work was retarded a year by flooding and winterkilling.

The Vitamin Content of Certain Pasture Grasses. (W. S. Ritchie and J. G. Archibald.) This project, inaugurated this year, is being conducted in cooperation with the Department of Chemistry, this department furnishing samples of several species of grass suitably prepared for feeding to white rats, and the Chemistry Department conducting the bio-assay. The project has been in effect only a few months and results are not yet available.

Progeny Performance in Sheep. (C. H. Parsons, R. C. Foley, and R. W. Phillips.) A cooperative project with the U. S. D. A. was started in 1932, using the Southdown and Shropshire flocks of sheep, in order to determine the inherent capacity of specific families or strains of sheep for the utilization of feed and the production of meat and wool, and to improve them by a study of the manner in which they transmit these characters.

Accurate records are kept on all sheep, including lambing records, gains in weight, type scores made on all lambs at 140 days of age, and carcass grades of all sheep slaughtered. The wool on each sheep is graded yearly, weighed, and samples are analyzed by the Bureau of Animal Industry of the U. S. D. A. A specialist from the Bureau visits the college at least once each year to counsel with a committee from the college in grading the mutton and wool characteristics of the flock. This contact helps to keep the records uniform and comparable with similar records at other institutions.

Sufficient records have now accumulated to give valuable information on the offspring of the sires used in recent years and a study is now being made of this material. This study includes four living rams and careful consideration will be given to the records of each before the 1936 breeding season. It is now possible to use proven sires in our flock of sheep.

Inheritance of High Milk Production in the May Rose Family of Guernsey Cows. (V. A. Rice.) A study was made of the Guernsey bull, May Rose King, through all his male offspring. The production of the daughters of this bull was ascertained, then the production of the 186 daughters of his 15 sons, then the production of the 746 daughters of his 86 grandsons, etc. The study comprises 1624 bulls and 10,406 cows having a total of 12,741 records. The 21 daughters of May Rose King averaged 14,068 pounds of 4 percent milk, while the weighted average for all the descendants of May Rose King is 13,598 pounds of 4 percent milk. These figures indicate that there has been no increase in average production in this family of Guernseys in the last 35 years, May Rose King having been born in 1901. The distribution of these 10,406 cows follows very closely the normal curve, indicating the results of a lack of selection for increasing milk production.

When these facts are plotted, it becomes possible immediately to locate the best bulls in the family. Within the same general line of breeding, there will be found bulls whose charts show a continual rise through six or eight generations, while other bulls in the same strain show a continual decrease.

The coefficient of inbreeding (Wright's Path Coefficient) for a group of high-transmitting bulls was 3.62 percent; for the medium-transmitting bulls, 2.73 percent; and for the low-transmitting bulls, 1.75 percent. It would seem that more rapid improvement might be made by the judicious and intelligent use of a greater amount of inbreeding on the part of our better breeders whose animals are selected for superiority in every respect.

A Fertility Test for Boars. (Ralph W. Phillips.) Observations on the semen of a number of boars have been made to determine the relation between the morphology of the spermatozoa and the fertility of the animal. Boars of good fertility have had as many as 172 abnormal spermatozoa per thousand. The maximum numbers of abnormalities found in any one part of the spermatozoon are as follows: abnormalities of the head, 50; of the neck, 120; of the middle piece, 12; and of the tail, 62. These last four figures all represent different animals. Abnormalities in the semen of boars of low fertility exceeded one or more of the above counts. Thus a boar might have no more than a normal number of all abnormalities except for an excess of those of the middle piece or of the neck; and this might be the only morphological indication of low fertility.

Development of the Testes and Scrotum in Farm Animals. (Ralph W. Phillips and Fred N. Andrews.) A study is being made of the testes of animals of various ages. Results to date show that spermatozoa are first formed in the testes of the ram at about 21 weeks of age, and in the bull between 25 and 32 weeks of age.

The tunica dartos muscle in the ram, which provides the mechanism for temperature regulation in the scrotum, develops a reaction to temperature changes at about nine weeks of age. This is the same time at which rapid development of the geminal epithelium of the testes begins.

Observations on a limited number of bulls indicate that a similar relation exists between the development of the tunica dartos and the testes.

Lambs that are castrated before the tunica dartos becomes sensitive to temperature changes fail to develop this sensitivity later. If castrated after the scrotum has become sensitive, the sensitivity tends to be lost.

Injections of 60 cock units or more of testicular hormone ("Hombreol") into a few lambs has resulted in some precocious development of the tunica dartos. Smaller doses gave negative results.

The above evidence indicates that the tunica dartos is dependent upon a testicular hormone for its development and function.

The Speed of Travel of Ram Spermatozoa. (Ralph W. Phillips and Fred N. Andrews.) The speed at which ram sperm travel in vitro in Ringer's and in normal salt solutions, over a distance comparable to the distance traveled in the ewe, has been found to be 4.6 mm. per minute. The rate is much faster at first and slower at later stages.

Seven ewes have been slaughtered at intervals of one half to seven hours after being artificially inseminated with semen diluted with Ringer's solution. At all stages sperm have been found in the upper section of the fallopian tubes. Previous work has set the time to cover this distance at five to six hours. The marked difference may be partially accounted for by the dilutor used.

Efficiency of Feed Utilization in Lambs. (Ralph W. Phillips.) A two-year study of the efficiency with which lambs utilize feed has shown that marked variations exist. In the first year's work, variations up to 17 percent were observed in seven Southdown lambs, and up to 41.2 percent in three Shropshires. In the second trial, variations up to 118 percent were observed in ten Shropshire lambs.

The Relation of Birth Weight to Growth Rate in Lambs. (Ralph W. Phillips.) A study of the birth weights of 108 Southdown lambs shows that lambs weighing 6 pounds and over have a better chance of surviving and make greater gains. Of all lambs weighing 6 pounds and under, 32 percent were born dead or died within a month after birth; while only a 7 percent loss was found in the heavier lambs. The heavier lambs also made greater gains during their first year of life.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Microbiological Examination of Dried Foods. (J. A. Clague and James E. Fuller.) Dried fruits and dried vegetables were examined for the numbers and types of microorganisms present. Dried fruits were found to be contaminated only on the surface, due to the fact that they are dried and marketed either whole or cut into halves. The microorganisms were not numerous and consisted largely of yeasts and non-pathogenic Gram-positive sporulating bacteria. Dried vegetables are marketed in powdered form and consequently the microorganisms present are mixed with the vegetable material. The microbial content of dried vegetables was much greater than that of dried fruits, but the same types of organisms were present. In addition some Gram-negative lactose-fermenting bacteria were found but these were not typical *Escherichia coli*. Artificial dehydration in a tunnel drier eliminated yeasts and reduced the numbers of bacteria and molds on dried fruits. *Escherichia coli* inoculated onto the surface of the fruits was killed. Dehydration was less successful in reducing the numbers of microorganisms, including added *Escherichia coli*, on dried vegetables. When vegetables were blanched before being dehydrated, *Escherichia coli* was destroyed by the process. Media found useful in the study were nutrient agar for bacteria, and tomato agar for yeasts and molds.

The Study of Media Employed in, or Suggested for, the Bacteriological Analysis of Water. (James E. Fuller and Evelyn D. Kimball.) This study was undertaken for the purpose of determining the suitability of the media in question for eliminating false presumptive tests caused by lactose-fermenting bacteria or combinations of bacteria not of the Coli-Aerogenes group, and for distinguishing the more significant from the less significant members of the Coli-Aerogenes group of bacteria. Media studied were lactose broth, brilliant green lactose peptone bile, the Dominick and Lauter medium, Endo's agar, eosin methylene blue agar, the Tonney and Noble ferrocyanide citrate agar, and MacConkey's bile salt agar. All media were prepared according to directions in the seventh edition of the Standard Methods of Water Analysis. Of the fluid media the brilliant green lactose peptone bile was most effective in eliminating organisms which have been shown to interfere with true presumptive tests, and those which may produce false presumptive tests. Of the solid media the Tonney and Noble agar seems to offer much promise for the elimination of Gram-positive organisms which in symbiosis give false presumptive tests. This medium verified the claims made for it by its originators in differentiating pure cultures of *Escherichia coli* and *Aerobacter aerogenes*. It was not so effective with intermediate members of the group.

Detection and Significance of Escherichia Coli in Commercial Fish and Fillets. (Francis P. Griffiths of the U. S. Bureau of Fisheries, James E. Fuller, and Ralph L. France.) This was a joint study of the U. S. Bureau of Fisheries and the Massachusetts Experiment Station. Twenty commercial haddock fillets and five eviscerated whole haddock purchased at local retail markets were examined for the presence of bacteria of the Coli-Aerogenes group. Weighed portions of ground fish flesh were inoculated into brilliant green lactose peptone bile broth. All organisms producing gas in this medium were isolated and their reactions determined by means of Endo's agar, Koser's sodium citrate medium, indol production, and the Voges-Proskauer and methyl red tests. Typical *Escherichia coli* was found on sixteen of the fillets and two of the eviscerated fish. Intermediate members of the Coli-Aerogenes group were frequently encountered on both fish and fillets. It seems probable that contamination of these fisheries products with bacteria of the Coli-Aerogenes group occurs after the fish are caught, and results from more or less careless methods of storage and marketing. It is suggested that the determination of bacteria of the Coli-Aerogenes group may be employed as a means of determining the cleanliness of methods by which fisheries products are handled.

Studies in Acid Production by Escherichia Coli and Aerobacter Aerogenes. (A. V. Syrocki, James E. Fuller, and Ralph L. France.) A report of preliminary work on this study has been published (*Jour. Bact.* 30: 211, 1935.) Briefly, the study showed that when pure cultures of *Escherichia coli* and *Aerobacter aerogenes* were grown in the Clark and Lubs medium containing 0.3 percent buffer (K_2HPO_4) and a small amount of finely ground iron metal, the iron dissolved in the acid produced by *Escherichia coli*, while the buffer prevented the production of sufficient acid by *Aerobacter aerogenes* to dissolve the iron. Dissolved iron was indicated by the addition of potassium ferricyanide solution to the cultures after incubation. Additional work is being done with intermediate members of the Coli-Aerogenes group of bacteria. In general the test for dissolved iron agreed with the methyl red test. Disagreement is noticed especially with organisms giving a weak methyl red positive test. These organisms frequently gave a negative test for dissolved iron.

The Influence of Bile and Bile Salts on Aerobacter (Bacterium) Aerogenes. (James E. Fuller.) A preliminary statement of this study has been made previously (Mass. Agr. Exp. Sta. Bul. 315, p. 21, 1935.) The medium employed was one percent each of Difco peptone, Difco lactose, and K_2HPO_4 in distilled water. Three series of cultures were set up: to one was added one percent of sodium taurocholate; to another one percent of sodium glycocholate; and to a third one percent of Difco ox bile. Twenty-five cultures of *Aerobacter aerogenes* were employed. These were typical on Endo's agar; they were Voges-Proskauer positive, and methyl-red, sodium-citrate, and uric-acid negative. Cultures were incubated at 37°C. Once each week transfers were made to fresh media of the same kind. Once each month the organisms were submitted to the tests mentioned above, and stained with Gram stain. The experiment was continued for five months with no change in the reactions mentioned. At first there seemed to be a tendency towards some variation in the Voges-Proskauer reactions but this was not persistent or uniform and was probably not significant. The organisms in all three of the media produced some unusual filamentous forms when they were viewed as stained specimens, but this characteristic disappeared immediately when the organisms were re-cultured on nutrient agar. There was greatly increased sliminess in most of the cultures in the three experimental media. This characteristic also disappeared after a few transfers of the organisms through lactose broth. The experiment indicated a definite persistence of cultural characteristics for the organisms examined, and consequently for the species.

Studies on the Methyl Red Reaction. (Ralph L. France.) The results of this investigation indicated that an increase of as little as 0.04 percent K_2HPO_4 in the standard formula for the Clark and Lubs broth caused irregular reactions with the *Escherichia coli* strains used in the experiment. A small increase such as this might easily be obtained by careless weighing or by varying amounts of water of crystallization in the K_2HPO_4. This may account for the variable results obtained by different investigators using this test. On the other hand, it was found possible to reduce the buffer 0.25 percent before variable results were obtained with the *Aerobacter aerogenes* strains used in the experiment.

A Study of the Action of the Coli-Aerogenes Group on Erythrosin. (Ralph L. France and James E. Fuller.) When *Escherichia coli* was grown in a Clark and Lubs broth with 0.3 percent K_2HPO_4 and 0.1 percent of erythrosin, and with the initial pH adjusted to 7.0, sufficient acid was produced to precipitate the erythrosin; but when *Aerobacter aerogenes* was grown under the same conditions, there was no precipitation of the dye. Further studies are being carried on with the intermediate members of the group.

A Study of the Eijkman Test. (Ralph L. France.) A study is being made of the Eijkman broth incubated at 46°C. as a presumptive medium for water analysis. At the present writing pure strains of *Escherichia coli* and *Aerobacter aerogenes* and the intermediate members of the group are being studied. Fecal strains of *Escherichia coli* will produce acid and gas in the dextrose broth at 46°C. *Aerobacter areogenes* strains will produce acid but no gas at this temperature. However, when the temperature is lowered to 45°C. the aerogenes strains will produce both acid and gas. This very slight difference in the temperature at which gas is produced by coli and by aerogenes indicates the need for a most accurate incubating apparatus. In this laboratory it was found that a water bath was more accurate than the standard bacteriological incubators. In the few studies made to date with the intermediates of the group, none produced acid or gas at 46°C. A few produced acid at 45°C., though none produced gas.

A Study of the Dye Tolerance of the Coli-Aerogenes Group. (Ralph L. France.) Because practically of all the recently devised presumptive test media for water analysis make use of dyes as inhibiting agents, a study is being made of the tolerance of the Coli-Aerogenes group for certain dyes. The dyes being used are gentian violet, crystal violet, basic fuchsin, methylene blue, and erythrosin. Data thus far obtained are insufficient to warrant the statement of any results.

Laboratory Service. (Ralph L. France.) Following is a list of the numbers and types of examinations made in the laboratory during the past year:

Milk (bacteria counts)	1,024
Ice Cream (bacteria counts)	100
Water	98
Miscellaneous:	
*Butter Fat (Milk)	80
*Solids (Milk)	1
Sediment (Milk)	9
Streptococci (Milk)	7
Watering (Milk)	1
Anaerobes	1
Total	1,321

*Analysis made by Feed Control Laboratory.

Studies on Steam Pollution. (Leon A. Bradley, John B. Belknap, and Carl F. Clancy.) Stream pollution caused by private and municipal raw sewage in near-by streams not only is a direct menace to health, but also has an indirect effect upon wild life, scenic beauty, property values, and recreation. An increased public interest in the recreational values of polluted areas will shortly demand a satisfactory solution of pollution problems. Studies on stream pollution in Amherst were made in cooperation with the local and state Health Departments. It was hoped that the results of this investigation might serve as a model for communities of similar size in the evaluation of the extent of stream pollution within their townships. Sanitary surveys of the watersheds of the principal drainage streams and the sewage treatment plant, including over 500 bacteriological analyses, were completed. Stream pollution was found which is serious enough to impair the suitability of the principal streams for bathing purposes. The surveys also indicated the sources and extent of this pollution. Recommendations were made for the improvement of local conditions.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.) Since the last report the F_3 generation of lines of the original crosses of the Red Currant Tomato with the Belmont, Success, and Break O'Day varieties, selected for resistance to the leaf-mold fungus *Cladosporium fulvum* Cke., were grown. In this growing, certain resistant lines were crossed with the varieties Field Station, Lloyd, and Baltimore to improve fruit size. In the F_1 growing of these hybrids 49 selections were made for the F_2 growing which is now under way.

The disinfection of the greenhouse interior with chemicals between crops offers a real problem. The burning of sulfur has serious objections. The combustion products of burning sulfur react with zinc wires, zinc white paints, and iron pipes and construction to form soluble metallic sulfates which on dripping on the plants of the succeeding crop cause an epidemic of burning. With the cooperation of Dr. E. B. Holland of the Department of Chemistry, the action of the fumes of burning sulfur on various white pigments used in paint are being studied.

Formaldehyde gas generated from liquid formaldehyde (37 percent) with potassium permanganate is lethal to spores of *Cladosporium fulvum* Cke., but at dosages and costs prohibitive in practice. Studies are in progress concerning the merit of hydrocyanic acid gas and of naphthalene as possible substitutes for sulfur, either of which, if successful, would greatly simplify the practice of cleaning up infestations of parasites between greenhouse crops without the harmful action on painted and metal surfaces or the production of plant poisons.

Vegetable Seed Treatments. (C. J. Gilgut, Waltham.) Dry chemical seed treatments were limited to two field trials of copper oxides, zinc oxide, Vasco, and Semesan. An excess of powder was added to the seed. The surplus powder was then screened off before planting. Red copper oxide gave the best stand of lettuce, and zinc oxide was almost as good. Zinc oxide proved best for cabbage, radish, carrot, and cucumber. Vasco, a commercial product containing zinc oxide, proved superior with turnip and spinach, although with spinach no significant contrast was shown between Vasco and zinc oxide. Semesan gave the best results with peas, beets, corn, and onion, although with beets red copper oxide was about as good. Red copper oxide which had turned black was distinctly injurious in these trials.

These trials contributed to the evidence that zinc oxide has considerable value in the treatment of vegetable seed for the control of damping-off.

Causes and Control of Decay of Winter Squash in Storage. (E. F. Guba and C. J. Gilgut, Waltham.) This project was suspended during the senior author's leave of absence. Temperature records are being kept in several storages for the storage season of 1935–36.

Up to this writing squash have kept unusually well in contrast to poor keeping up to this time in other years. Observations seem to indicate that the unusually dry growing season is a major contributing factor. To this may be added the dry, cool weather conditions prevailing after harvest, which have aided in the maintenance of dry storage conditions.

Carnation Blight. (E. F. Guba, Waltham.) Cooperative experiments designed to demonstrate the effect of Bordeaux on carnations as a protection against blight caused by *Alternaria dianthi* S. & H. have been arranged with several carnation growers in cooperation with the New England Carnation Society. This project will be terminated with these tests.

Diseases of Herbaceous Ornamental Plants caused by Soil-Infesting Fungi.[1] (W. L. Doran.) Cuttings of *Nepeta Mussini* rooted as well in disinfested soil as in sand and with no more damping-off. In similar cases soil may be preferred, for cuttings of this species made about 50 percent more growth in five weeks after insertion in soil than in sand.

Formaldehyde in quantities safe with seedlings was not safe with some cuttings, and 7 c.c. injured *N. Mussini* inserted in soil 24 hours after treatment.

An 18 percent acetic acid dust (of charcoal) did not injure seeds sown within 24 hours after soil treatment, improved germination, and prevented most damping-off in naturally infested soil, but not in soil heavily inoculated with *Pythium* spp. Like formaldehyde, acetic acid is volatile so there may be some reinfestation of soil while seedlings are still susceptible.

When ethyl alcohol 1:50 was applied 10 days before seeding, there was less damping-off, also better growth, of sweet pea and China aster. It was injurious when applied immediately before seeding.

Raw pyroligneous acid 4:100 gave fair control of damping-off, but the concentrated acid at this dilution was not equally effective.

Antimony and potassium tartrate 8 gms. reduced the severity of damping-off in a naturally infested soil, but not in a soil heavily inoculated with *Pythium debaryanum.*

Hollyhock is apparently tolerant of or even benefited by more copper than some other species can stand. Its growth was improved by copper lime dust 20 gms. and by metallic copper 9 gms., although the latter injured Ageratum and Petunia. Both of these treatments prevented most damping-off. Copper aceto-arsenite 1 gm., which gave some degree of control of damping-off, and cuprous cyanide 2 gms. were harmless to hollyhock although injurious to Ageratum, Salpiglossis, and cucumber.

Tannic acid 3 to 15 gms. did not prevent damping-off and caused but little change in soil reaction, but did improve growth of common foxglove.

Ethylic aldehyde 1:40, 9 days before seeding, did not satisfactorily control damping-off, but did improve the germination of several species, also the growth of sweet pea.

Salicylic acid 4 to 7 gms. did not affect damping-off, but did improve germination of cress, beet, and cucumber (and also *Rhododendron molle*).

Neither potassium permanganate 15 to 30 gms. nor sulfur 6 to 20 gms. satisfactorily controlled damping-off in soil inoculated with *Rhizoctonia solani* and *Pythium debaryanum.*

In the amounts used, the following have been toxic to plants or have failed to prevent infection: acetamide, ammonium persulfate, auramine yellow, beta-naphthol, boric acid, brilliant green, calcium hypochlorite, cerium oxalate, lead acetate, magnesium superoxol, nickel oxide, orthocresol, orthochlornitrobenzene, oxalic acid, oxyquinoline sulfate, and sulfocarbolic acid.

Damping-Off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modifications of Environment. (W. L. Doran.) Softwood cuttings of *Cotoneaster divaricata, Enkianthus campanulatus, Rhododendron yedoense, Viburnum Carlesii,* and *V. Opulus nanum* rooted well when inserted in sand in the greenhouse on May 20 to 24. Similarly inserted and at the same time, cuttings of the following species rooted poorly or not at all: *Calycanthus floridus, Prunus triloba, Rhododendron minus, Rhus canadensis,* and *Stephanandra Tanakae.*

---

[1] In the report on this and the following project, number of grams chemical per square foot of soil is indicated. In the case of solutions, 2 quarts per square foot was used. Soil or other media was 3 inches deep in flats. Soil used was either naturally infested or, after autoclaving, was inoculated with the fungi.

All cuttings of *Viburnum fragrans* rooted when inserted June 21, but less than one-third rooted when inserted July 10. *V. Sieboldii* also rooted better when taken early.

Taken June 21, *V. fragrans* and *Corylopsis pauciflora* rooted as well in sand and peat moss as in sand. *Rhododendron calendulaceum* rooted better in sand. *Gordonia alatamaha* rooted fairly well in sand, but did not do well when transplanted to soil (pH 6.0).

Buddleia alternifolia, Philadelphus coronarius, Viburnum bitchuiense and *V. Carlesii* did not root so well in soil as in sand or in sand and peat moss. The unfavorable effect of soil is not attributed to fungi present, for the cuttings died without previous evidence of decay of tissue, and results were the same in soil variously sterilized.

The use of acetic acid dusts, harmless to seedlings, was followed by some defoliation of cuttings of *Bruckenthalia spiculifolia, Erica vagans, Ilex crenata,* and *I. opaca* inserted immediately after treatment of the rooting medium (sand and peat moss).

The only chemical treatment of sand which gave indications of any stimulation of rooting of softwood cuttings, in this case *Lonicera syringantha* and *Styrax americana,* was copper-lime dust 16 gms.

Softwood cuttings of 13 species rooted no better in sand or sand and peat when the media received the following treatments, than in these media without treatment: acetic acid 4 c.c., formaldehyde 6 c.c., tannic acid 12 gms., potassium permanganate 15 gms., and magnesium peroxide 2.5 gms.

Growing in inoculated soil, cuttings of *Taxus media* taken in October were much less susceptible to infection by a strain of *Pythium debaryanum* than were seedlings of herbaceous plants; but cuttings of *Taxus baccata repandens,* similarly exposed, were infected and killed by a strain of *Rhizoctonia solani.*

Germination of the seeds of *Rhododendron molle* and early growth of seedlings was improved by salicylic acid 3 gms. applied to a mixture of sand, peat moss, and soil.

Apple Rust. (C. J. Gilgut, Waltham.) A great reduction of rust (*Gymnosporangium juniperi-virginianae* Schw.) on Wealthy apple leaves was obtained by the use of several fungicides. Six applications each were made of Flotation sulfur, Linco colloidal sulfur, liquid lime-sulfur, and a combination spray consisting of liquid lime-sulfur, calcium arsenate, and aluminum sulfate. The first applications were made to conform to the pre-pink bud stage of tree growth; the last, on June 14, corresponded to about three weeks after calyx time. The percentage of control was 88, 92, 96, and 95 respectively. The results were computed on the basis of 0 percent control for the trees given no treatment.

This work was done in cooperation with Dr. J. H. Faull of Harvard University and Dr. J. D. MacLachlan, one of his graduate students.

Shade Tree Disease Survey of Massachusetts. (A. Vincent Osmun and Malcolm A. McKenzie.) A survey to determine the presence, distribution and importance of shade tree diseases in the State was carried on during the summer of 1935. The work was financed jointly by State appropriations to the College and State Department of Agriculture, a State-wide F. E. R. A. project, and coordinating town projects. The total number of people employed was 530, including scouts, supervisors, laboratory technicians, and stenographers. Follow-up work in the laboratory is still in progress. Scouting was done in every town in the State. Some 4,000 diseased specimens were received at the laboratory, requiring the making and reading of 16,000 cultures. Forty-one shade tree diseases were reported, 13 of which were diseases of the American elm.

The primary purpose of the survey was to determine whether the so-called Dutch elm disease, caused by *Ceratostomella ulmi* (Swartz) Buisman, was present in the State. This disease was first discovered in Holland in 1919 and within a few years had spread over practically all of northwestern, central, and southern Europe, virtually wiping out the elms in much of that area. In 1930, it was discovered in the United States. At that time a few affected trees were found in Ohio and these were promptly destroyed. A much larger outbreak was discovered in the vicinity of New York Harbor in 1933. This area, embracing portions of New Jersey, New York, and Connecticut, is about 6,000 square miles in extent, with the center at the tip of Manhattan. Within this area some 10,000 elm trees have been found affected with this disease and destroyed because of it. A few isolated cases have appeared in Maryland, Virginia and Indiana.

The Dutch elm disease is not known to be present in Massachusetts. It has been found, however, at two points within forty-five miles of the southern border — at Old Lyme, Connecticut, and in Putnam County, New York. In southwestern Connecticut, only a few miles farther away, approximately 100 trees have succumbed to the disease.

Proximity of the disease in Connecticut and New York, known entrance at Massachusetts ports of elm burl logs and other elm stock from Europe, and the presence in the State for at least twenty-six years of the principal known carrier, the smaller European elm bark beetle (*Scolytus multistriatus* Marsh) furnish ample reason for concern and justification for this survey.

Prompt destruction of every elm tree found to be affected offers the only hope of eradicating or checking the spread of this disease. Therefore, there should be provision for prompt eradication measures in case the disease is discovered in this State.

While the survey did not result in discovery of the Dutch elm disease, a large amount of significant and valuable data concerning other diseases of shade trees was gathered and an intensive study of this material is in progress in the laboratory. A number of elm diseases similar in effect to the Dutch elm disease were found prevalent and causing heavy damage. Among these, diseases caused by the fungi *Cephalosporium* sp., *Verticillium dahliae* Klebahn, and *Fusarium* sp. were the most frequently reported.

The entomological phases of this work have been conducted by the Department of Entomology.

Monograph of the Genus Pestalotia. (E. F. Guba, Waltham.) This is not an official project and the work has been done entirely on the author's own time. During a leave of absence from April 1 to October 1, 1935, progress advanced to a point warranting the assemblage of material for publication. The preparation of the manuscript is now in progress.

Testing Plants with Diphenylamine. (L. H. Jones.) This test for nitrogen deficiency has limitations which are more concerned with the plant under consideration than with the test itself. Thus the base of the petiole may be used from geranium, tomato, primrose, and begonia. From fuchsia, the node or above and below the node may be used. With *Asparagus Sprengeri*, old or new shoots cannot be used. With the rose, the test should not be made on a part where active growth is taking place. An actively growing plant part may give a negative test because the nitrate is being utilized in growth. The test is useful in determining misuse of fertilizers, as the resultant injuries are frequently attributable to a high nitrate content of the fertilizer mixture. There is considerable variation in results of tests when ammonium sulfate is used as a source of nitrogen for nitrogen deficient plants. Indications sometimes point to a photochemical effect in which the ammonium ion is transformed to the nitrate ion.

Slow Response of the Gardenia to Certain Stimuli. (L. H. Jones.) Gardenias are relatively slow in responding to certain treatments. Fuchsia and geranium responded to various forms of nitrogen in 8 to 10 days. Under the same conditions the gardenia did not register a response for 23 days. Nitrate salts are not very effective on gardenias in small pots as the plant requires such heavy watering that leaching quickly occurs. Urea or ammonium sulfate are, perhaps, the most rapid in giving a response, but organic sources of nitrogen might be preferred on the basis of giving a slower, but sustained response.

A concentration of hydrocyanic acid gas strong enough to kill all the leaves on a geranium plant failed to injure a gardenia plant. The gardenia plant responded by pointing its leaves more directly upward and the young leaves curled in. The plant was again normal within 72 hours after exposure.

There were considerably more abscised buds on gardenia plants exposed to low temperatures than on plants kept at the normal greenhouse temperature. The data are incomplete owing to the small number of plants and buds involved.

Removal of the terminal shoots of plants stimulates formation of axillary shoots. The order of macroscopic development of the bud in the axil of a leaf is appearance, then swelling, and finally bursting of the bud. In these tests the time was measured between the pinching-back of the terminal shoot and the bursting of the axillary bud. Healthy plants of geranium, petunia, and rose required but 7 days; the gardenia required 20 days.

The gardenia was found to be characteristically slow in its responses to the treatments given.

The Water-Holding Capacity of Mixed Soils. (L. H. Jones.) The addition of peat to a soil increases the wilting coefficient as well as the water-holding capacity. Such soils may *feel* moist when actually the moisture present is not available for the plant. The use of large amounts of inorganic fertilizers on such soils, particularly in the greenhouse, increases the osmotic concentration of the soil solution to such an extent that heavy watering should be practiced to avoid leaf injury from the concentrated soil solution.

A formula for calculating the probable water-holding capacity of a mixture of two or more soils by volume is fairly accurate if the final volume is equal to the sum of the volumes mixed. However, it usually happens that the final volume is less than the sum of the volumes because the smaller elements of a fine soil fill the interstices of a coarser soil. This is particularly true when peat is used. In such cases the formula gives a higher calculated value than is found by an actual determination.

Plant Containers. (L. H. Jones.) A plant container of paper designed for tree nurseries has been in use for more than a year. No deterioration of the paper has occurred. However, it is recommended that such containers be insulated from a moist soil beneath the pot by thin boards or heavy asphalted paper. This insulating procedure prevents the roots from going through the pot into the ground.

A cheap metal container made for use in the home or greenhouse has been tested. When the metal is properly protected with paint, rusting is prevented and the life of the container is prolonged. Satisfactory growth was obtained with and without drainage holes.

The nutrient problem of maintaining the vigor of a plant in any type of plant container seems solved by using plant nutrient material carrying nitrogen in an organic form. This not only sustains growth, but also keeps a balance between foliage and flowers.

DEPARTMENT OF CHEMISTRY

W. S. Ritchie in Charge

The Effect of Fertilizer and Cultural Treatment on the Composition of Havana Seed Tobacco. (E. B. Holland.) Samples of the web from the various grades of leaf of the 1934 crop were prepared for analysis as a supplementary measure and are held for examination if needed.

The Copper, Iron, Manganese, and Iodine Content of Fruits and Vegetables Used as Human Foods. (E. B. Holland, C. P. Jones, and W. S. Ritchie.) Twenty-six new samples bought on the market have been added to the number collected in previous years. The analytical work has been continued on these samples representing the more common fruits and vegetables. The determination of iron, copper, manganese, phosphorus, total ash, and acid soluble and insoluble ash has been completed on fifty-six samples.

Absorption by Food Plants of Chemical Elements of Importance in Human Physiology and Nutrition. (E. B. Holland, W. S. Ritchie, and W. S. Eisenmenger.) Beets, carrots, onions, lettuce, and spinach were raised under special fertilization during the past season to determine the ability of these crops to assimilate copper, iron, manganese, and iodine. Thirty samples were secured and added to the number available for analysis under the preceding project.

Cooperative Analytical Service. (The Department.) This includes cooperative investigations with the Waltham Field Station on the effect of storage on the composition of celery, the cause and prevention of chlorosis on gardenias, and the actual source of injury to greenhouse plants from burned sulfur.

Additional samples of normal rutabagas and those affected by "dark centers" were analyzed.

The effect of automobile mileage on the composition of lubricating oil was also studied.

Bordeaux mixture 5–5–50 and basic copper sulfate with Wyo-Jel were applied to potatoes in cooperative field tests. There was practically no blight, and Bordeaux proved a better repellent for aphids, flea beetles, and leafhoppers than the basic sulfate mixture.

Testing Analytical Methods. (The Department.) Analytical methods have received considerable attention due to the interference of some vitiating product in a few samples. Complete oxidation by wet combustion was found difficult in some cases and a clear colorless solution did not prove a safe guide.

The study of the methods for determining iodine in vegetative organic material has been continued. A method now being developed is believed to be an improvement on those now in use.

Nitrogen Fixation in the Presence of or as a Result of the Growth of Legumes Versus non-Legumes under Certain Defined Agronomic Conditions. (F. W. Morse.) Oats and field peas were grown together on the legume sections and oats alone on the non-legume sections. Nitrogen was applied to Plots 5, 8, and 10. Oats responded to nitrogen more than oats and peas and excelled in dry matter, but without nitrogen oats produced less dry matter than oats and peas. The results of 12 years (1924 to 1935 inclusive) have been prepared for publication in a station bulletin.

On the plots without nitrogen fertilizers since 1882, the continuous cropping with non-legumes for 12 years has reduced the fertility of the soil; on the other hand alternation with legumes has not increased it. The average annual production of dry matter on the non-legume sections is on a lower level than on the legume sections.

Chemical Study of Cranberries. (F. W. Morse.) Work on this project has been devoted to improving the method for the determination of quinic acid.

A Study of the Availability of Soil Potash with the Object of Developing a System of Diagnosis for the Soils of the State. (F. W. Morse.) This project was completed with the publication of Bulletin 324 in August.

The Carbohydrates of Kentucky Blue Grass. (Emmett Bennett.) The carbohydrates present at different periods of growth are being determined in order to ascertain the transformations which these fractions may undergo during the life of the grass.

In addition to the identification and determination of some of the more common sugars and complex polysaccharides, identification tests are being made for one uncommon free sugar found to be present. One hemicellulose has been isolated and is now being investigated in an attempt to identify the hydrolytic products.

The Nutritive Value of Fishery Products as Human and Animal Foods. (W. S. Ritchie and C. R. Fellers. Cooperative with Horticultural Manufactures.) Under this project a rather complete study is being made of the chemical composition and nutritive value of the haddock as affected by commercial processing. The samples are being obtained through the cooperation of the Birdseye Frosted Foods Sales Corporation, and represent four different conditions: fish frozen with dry ice immediately after catching, the whole fish frozen at the pier, and commercial fillets prepared by the so-called quick and slow methods of freezing. Nutritional studies are being made of these samples to determine their value for growth, reproduction, and lactation, using the albino rat. Determinations of ammonia, total protein, water soluble and insoluble protein, fat, and total ash are made on current samples. Samples are being saved for the determination of certain of the inorganic constituents.

The Vitamin A Content of Certain Pasture Grasses. (W. S. Ritchie and J. G. Archibald. Cooperative with Animal Husbandry.) The grasses used for the vitamin assay were grown under different soil and fertilizer conditions by the Animal Husbandry Department, the Chemistry Department making the bio-assay. Twenty-one samples of grasses were used in making the assay, which at present does not indicate a great variation in the vitamin A content under the conditions of the investigation.

THE CRANBERRY STATION

(East Wareham, Massachusetts)

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Dust Insecticides. Several thousand acres of cranberry bog were dusted commercially during the season of 1935 with mixtures of fine ground pyrethrum and gypsum and pyrethrum and clay, largely for the purpose of controlling tne blunt-nosed leafhopper (*Ophiola*) and the blackheaded fireworm (*Rhopobota*). The season's extensive experience led to the following conclusions:

1. A mixture with 30 percent of high-grade pyrethrum, 100 pounds to the acre, is entirely satisfactory as a general control for the blunt-nosed leafhopper under Cape Cod conditions.

2. Results with the 30 percent pyrethrum mixture applied to severe infestations of the blackheaded fireworm and blunt-nosed leafhopper varied materially and often failed to be entirely satisfactory. It is not known whether this was due to unknown differences in the materials used, in the method of application, in the weather, or in the vines, to a combination of these differences, or to some other cause.

3. Entirely satisfactory control of these pests was obtained when the amount of high-grade pyrethrum in the mixture was increased to 50 percent or more. Unmixed pyrethrum at the rate of 60 pounds to the acre was also entirely effective.

As pyrethrum for use in 1936 is offered at very low prices, it may be best to use it in these greater amounts against severe infestations.

4. Adults of the cranberry spittle insect (*Clastoptera*) were checked effectively with 100 pounds of the 30 percent pyrethrum mixture to the acre. This method of control should be used if earlier treatment has been neglected, but this insect should be stopped as soon as the spittle masses appear on the vines.

5. On the whole, gypsum seemed to be a much more satisfactory diluent for pyrethrum than clay.

Airplane Dusting. With the cooperation of some of the cranberry growers and a company offering agricultural air service, extensive tests of the possibilities of this method of dusting cranberry bogs were carried out, over a hundred acres being treated. The machine was handled with great skill and showed that airplanes may prove to be useful on bogs of over twenty acres. It was evident, however, that a flying technique for an evener distribution of the dust over a bog area will have to be developed. This will require careful selection of weather and marking off into lanes of areas to be treated. It appeared also that, to be effective, much more pyrethrum must be used than with ground dusters. With the prospective low cost of this material, this may not be an insuperable objection. Airplanes as at present developed can never be used to advantage on small bogs because the maneuvering required is difficult and very extensive in proportion to the area treated, and therefore costly.

Kerosene Vapor and Pyrethrum Extract. The experience with kerosene in cranberry bog weed control work given below suggested an immediate trial of its use with pyrethrum as a possible cheaper treatment for blunt-nosed leafhopper and blackheaded fireworm. Several plots on different bogs were treated with a paint sprayer, water-white kerosene alone being applied on some and kerosene with pyrethrum extract on others. No injury from the treatment to vines or crop appeared on any of the plots, even where the kerosene was used on vines in full bloom at the rate of ten gallons an acre. Seven gallons to the acre of the kerosene with pyrethrum reduced the leafhoppers and fireworms effectively. There was about twice as much pyrethrum in the mixture as is used commonly in commercial fly sprays. The success of these tests suggests that further work should be done along this line.

Trichogramma. It has long been known[1] that the Chalcidid, *Trichogramma minutum* Riley, is the most important parasite of the cranberry fruit worm. This egg parasite is now bred commercially for use in the control of certain insect pests in the South. Through the courtesy of Dr. A. W. Morrill, president and manager of California Insectaries, Inc., Glendale, California, the cranberry station received 150,000 of the yellow form of this parasite (regarded by some as *Trichogramma pretiosa*) for experimental work with the fruit worm. These parasites were liberated on two sections of the Agawam bog of the Fuller-Hammond Co., near East Wareham, each of these sections being exactly an acre in area. On one section, 50,000 of the parasites were liberated on July 17 and 25,000 on July 25; on the other, 25,000 were liberated on July 18 and 50,000 on July 26; so there were 75,000 parasites in all put out on each of these sections. They were in good condition and very lively when they were distributed and the weather was warm and dry, no rain occurring for a day or two after any of the liberations.

Berries were gathered from all parts of the two areas over which the parasites had been distributed as well as from an adjoining section on which no parasites had been placed, and the fruit worm eggs on them were examined for parasitism and hatch, with results as follows:

	Areas with Parasites		*Area without Parasites*
Date of distributing parasites	July 17 and 25	July 18 and 26	—
Date of examining berries	August 1	August 8	August 9
Eggs unparasitized and hatched	333	276	169
Eggs unparasitized and unhatched	12	2	1
Eggs parasitized, number	45	13	16
Eggs parasitized, percent	12–	4+	9–

Examinations were also made of fruit worm eggs on berries collected on other bogs, within five miles of the bog on which the parasites were liberated, with findings as follows:

	Zion Bog	*Burgess Bog*	*Savary Bog*	*Dodge Bog*
Date of examining berries	August 3	August 5	August 7	August 8
Eggs unparasitized and hatched	38	20	218	50
Eggs unparasitized and unhatched	4	3	18	29
Eggs parasitized, number	173	4	82	17
Eggs parasitized, percent	80+	15–	26–	18–

The *Trichogramma* parasitism of fruit worm eggs on three bogs near Harwich was found to be 0, 16, and 17 percent, respectively.

All this shows that no material advantage was obtained by the liberation of the yellow form of this parasite, in spite of the fact that it readily attacked fruit worm eggs in laboratory tests. Only the dark form, however, parasitizes this pest in nature and it might prove more useful. Fruit worm eggs infested with this form were sent to Dr. Morrill and he is breeding it for field tests next year.

---

[1] Bul. 160, Mass. Agr. Expt. Sta., 1915, pp. 110 and 111; and Bul. 168, Mass. Agr. Expt. Sta. 1916, pp. 39 and 41.

Blackheaded Fireworm (*Rhopobota*). A very unusual outbreak of the second brood occurred on numerous bogs scattered throughout the cranberry growing region, many that had not been attacked by this pest for a long period of years being seriously affected. This may have been due to the abnormally cool period in which the first brood developed, this weather probably having been unfavorable to the development of the fungus (*Entomophthora*) which largely controls this fireworm.

Apple Sphinx (*Sphinx gordius* Cram.). This insect broke out on an area of fifteen acres in such numbers that it threatened to destroy the whole crop. Treatment with the usual stomach poisons seemed undesirable as the berries were partly grown, the winter water having been drawn off early. The bog was treated on August 12 with a dust mixture of one part of Derris (4 percent rotenone) and 4 parts of clay, 100 pounds to the acre. The worms stopped feeding at once and all died within five days. The largest worms were full grown.

Control of Cranberry Bog Weeds. (Wm. H. Sawyer and H. J. Franklin.) Because of the urgency of service in weed control, Dr. Wm. H. Sawyer was employed temporarily on funds provided by the Cape Cod Cranberry Growers' Association to carry on work in this field. It is hoped that this service may be extended.

Hand Weeders. Some new types of these tools were developed and are likely to be useful under some bog conditions.

Chemical Weed Killers. Experiments were conducted with fuel oil, kerosene, gasoline, sodium arsenate, sodium chloride, and iron sulfate, with the following results most important:

1. The light oil, gasoline, goes into the interior of leaves readily and so is very harmful to cranberry vines as well as weeds.
2. The heavier oil, fuel oil, evaporates so slowly that it is also very harmful to cranberry vines and weeds alike.
3. Kerosene, intermediate between gasoline and fuel oil in viscosity and volatility, doesn't get into the leaf interior much and evaporates rapidly enough to be only slightly harmful to the smooth cranberry foliage.
4. Kerosene sprayed on grasses, rushes, and sedges collects inside their sheaths and remains there many days after it is applied.
5. Because of all this, water-white kerosene, used at the rate of 100 to 400 gallons an acre, according to the grass, rush, or sedge concerned, is a good control for many of these weeds and probably can be used to real advantage to clear many bogs of them. The following weeds of this sort were killed largely or entirely by experimental applications of the kerosene:

Juncus rushes
Bunch grass (*Scirpus*)
Dulichium arundinaceum (L.)
Cyperus sp.
Carex trichocarpa Muhl.
Carex scirpoides Schkuhr.
Beak rush (*Rynchospora*)
Panicum virgatum L.
Panicum mattamuskeetense Ashe

6. Young seedlings of beggar-ticks (*Bidens*), one to two inches tall, are killed readily with dry iron sulfate, 1¼ tons to the acre.

7. Wild bean or ground nut (*Apios tuberosa* Moench.) is readily killed back to the ground by spraying with 7 pounds of sodium arsenate in 400 gallons of water to the acre. If this spray is applied when the cranberry vines are in bloom, it may burn a few of the blossoms and more tender tips. After the berries are set, the injury is negligible. The continued use of this spray for two or three years should eliminate this weed entirely. This is a refinement of a treatment advocated heretofore.[1]

8. Green moss (*Polytrichum commune* L.) can apparently be killed very readily with a spray of iron sulfate, 3 pounds to the gallon of water, 800 gallons to the acre. This is probably the best treatment so far found for moss. It should be applied in the late fall or early spring, when the cranberry vines are dormant, and should be followed by a good resanding after ten days to two weeks.

9. Violets (*Viola lanceolata* L.) can be killed with dry iron sulfate, 1½ tons to the acre.

COOPERATIVE CRANBERRY INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station

H. F. Bergman, Senior Pathologist, U. S. D. A., in Charge

Development of Strains of Cranberry Resistant to False Blossom. (H. F. Bergman and W. E. Truran.) Reciprocal crosses between Early Black and McFarlin represent the larger part of the cross pollinations made during the past season. Sixty fruits were secured from each of these combinations. Reciprocal crosses were also made between McFarlin and Shaw's Success and between Paradise Meadow and Shaw's Success. A few crosses of Early Black x Shaw's Success, of Paradise Meadow x Early Black, and of Paradise Meadow x McFarlin were made, the last being a new cross.

Seeds from crosses made in 1934 were planted this year. Germination was poor in all cases. Seeds from the cross of Early Black x McFarlin gave the highest percentage of germination, 32 percent. Most of the seedlings were killed by damping-off fungi but some seedlings of each cross survived. These have been transferred to pots and are to be set out on the bog next spring.

Oxygen Content of Flooding Water in Relation to Injury to Cranberry Vines. (H. F. Bergman and W. E. Truran.) Measurements of the oxygen content of water and of the light intensity at various depths were made on several flooded bogs to ascertain the relation between these two factors. Light measurements were made by means of a photoelectric cell which could be submerged to the desired depth. The light intensity as measured by this method is about 25 percent less at midday on bright days at a depth of 1 foot in clear water than it is above the water surface. During the early forenoon and late afternoon, on cloudy days, or in colored water the reduction in light intensity at that depth may reach 50 percent of that above the water surface. The oxygen content of flooding water varies with changes in light intensity, but no definite relations between the two can be made at this time as the calculations from data secured have not been made.

---

[1] Bul. 305, Mass. Agr. Expt. Sta., 1934, p. 23.

Measurements of the oxygen content of water and of light intensity at different depths were made during the last few days of flooding on a bog near Barnstable which was flooded for 12 days during August. The oxygen content was at no time found to be low enough to cause injury as judged from previous experiments and observations. No immediate injury was noticeable externally after the water was withdrawn. Observations will be made again next June to see if the prolonged flooding affected flower bud formation.

Spraying and Dusting Experiments. (H. F. Bergman and W. E. Truran.) Two applications of two mercurial sprays made up either ½ or 1 pound to 50 gallons of water and applied at the rate of 250–300 gallons per acre were much less effective in controlling rots than two applications of 5–3–50 Bordeaux applied at the same rate. The Bordeaux spray reduced the amount of rot to ¼–½ of that in adjacent check plots.

On another bog a 25–75 mixture of monohydrated copper sulfate and chemically hydrated lime dusted onto dry vines or the same mixture dusted onto wet vines at the rate of 100–150 pounds per acre gave little or no control of rots. On 7 plots sprayed with a 5–3–50 Bordeaux mixture the amount of rot was reduced to half or less of that in adjacent check plots. Three out of the 4 plots dusted wet and the 3 plots dusted dry showed not more than 10–20 percent reduction in rot as compared with adjacent checks. The reduction in rot on one of the plots which was dusted when the vines were wet compared favorably with that on plots sprayed with Bordeaux. The application of dust on this plot was 2–3 times as great as on other dusted plots.

Three commercial fungicidal dusts consisting of monohydrated copper sulfate and chemically hydrated lime plus sticker, and a dust made up of 25 pounds of monohydrated copper sulfate, 50 pounds of bentonite, and 25 pounds of chemically hydrated lime were used on a series of plots on another bog. Two of the commercial dusts contained 20 percent of monohydrated copper sulfate, the third 25 percent. Two applications at the rate of 40 pounds per acre were made on dry vines. Rots were not controlled by any of the dusts.

In a test carried out on the State Bog in cooperation with Dr. H. J. Franklin, the use of a 40–60 sulfur (300 mesh) — pyrethrum mixture as a combined insecticide and fungicide proved to be unsatisfactory as a fungicide. Three plots were dusted twice at the rate of 60 pounds per acre at each application; one plot, 40 pounds on the first application, 60 pounds on the second; one plot, one application of 40 pounds; one plot, one application of 60 pounds. Check plots alternated with dusted plots. The yield on all dusted plots, except the one which had only one application of 40 pounds per acre, was noticeably less than that of adjacent check plots. The amount of rot in the berries, at the time of picking, was also greater in all but one of the dusted plots than on adjacent check plots. By the end of October the amount of rot in berries from this plot had exceeded that of the check plots on either side of it. Small local areas of injury to vines were evident in August on some of the dusted plots. The greater amount of rot in berries from dusted plots than in those from check plots is probably due to slight injuries to flower buds and young fruits which favored the invasion of fungi.

Storage Tests of Cranberries. (H. F. Bergman and W. E. Truran.) Two applications of 5–3–50 Bordeaux were more effective in controlling rots up to December 1 than other treatment although the degree of control was not as great as has been obtained in other seasons. The loss due to storage rots in berries from most of the plots sprayed with Bordeaux was about half of that in berries from check plots. Two applications of mercurial sprays did not reduce storage rots more than 30 percent as compared with check plots and in some instances much less than that. In berries from plots dusted twice with copper sulfate–lime dust on wet vines the loss up to December 1 was only about 10 percent less than that in berries from check plots. The same dust applied to dry vines had no effect on storage rots. In berries from plots dusted once or twice with a combined insecticidal—fungicidal dust containing sulfur, the loss due to storage rots to December 1 was not only not reduced but was noticeably greater than in berries from plots not dusted.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Explanation for High Initial Aging Temperature Phenomenon of Gelatin Solutions. (W. S. Mueller.) In two previous studies it has been shown that the initial aging temperature has a great influence on the basic viscosity and gel strength of a gelatin–water solution and also of ice cream mixes containing gelatin. When such solutions were divided after pasteurization and one part promptly cooled and aged at 40°F., while the other part was cooled to 68°F., held at that temperature for four hours and then cooled and aged at 40°F., the latter had a considerably firmer gel structure. Various initial aging temperatures, from 50° to 149°F. were tried. It was found that temperatures above 99.8°F. did not increase the gel strength. The maximum increase in gel strength was produced at 68°F. and when an ice cream mix was held for four hours at this temperature the efficiency of the gelatin was increased to such an extent that the gelatin content could be reduced approximately one fourth without any loss in quality of the finished product.

In order to find a possible explanation for this interesting phenomenon, optical rotation and Tyndall studies were undertaken. Aging for 4 hours at 68°F. plus 20 hours at 40° was compared with aging for 24 hours at 40°. The optical rotation was the same for both treatments. Observations with a photoelectric tyndallmeter showed a slight increase in light-scattering ability of the solution when the high initial aging temperature was used. These results indicate that the phenomenon associated with high aging temperature is due to changes in size or number of micellae and not to a rearrangement within the gelatin molecule. Other physical properties of the gelatin solution must be studied before definite conclusions can be drawn.

Nutritive Value of Milks — Plain versus Chocolate Flavored. (W. S. Mueller and W. S. Ritchie, Department of Chemistry.) The consumption of chocolate milk has increased during the last few years to such an extent that it has now become an important dairy product. However, the nutritive value of cocoa is still a debatable question and the question of whether cocoa should be included in children's dietaries is far from being settled. Most of the reported experimental work on this problem is controversial.

The extensive use of cocoa has been criticized because it contains theobromine, and to a lesser extent caffeine. Another objection raised to chocolate milk is its sugar content, which is considerably higher than that of whole milk. It has been generally conceded by other investigators that the tannic acid content is too small to be of any significance; yet the cacao red content is high, being from 2 to 5 percent, and it resembles tannin in many of its properties. It has been reported that tannin will decrease the solubility of milk solids and that the addition of cocoa to other articles of food seems to reduce the total amount of nitrogen absorbed. In view of these reports this project was organized with the purpose of demonstrating by animal feeding experiments whether the addition of cocoa to milk is harmful, beneficial, or indifferent. Considerable progress has already been made in this study.

Mineralized chocolate milk containing 1 percent cocoa had no noticeable harmful effects on white rats receiving this diet for 17 weeks, while the addition of 4 percent of cocoa to the milk was harmful.

Some Factors Affecting the Properties of Whipped Cream. (W. S. Mueller, M. J. Mack, and H. G. Lindquist.) In this investigation the following properties of the unwhipped and whipped cream were studied: Viscosity, maximum stiffness, whipping time, overrun, amount of drainage, and fat content of the drainage.

A mechanical whipper of constant speed was used for whipping the cream. Relative stiffness of the whipped cream was determined by measuring the input of the whipper motor in watts at intervals of ten or five seconds throughout the whipping process. The relative whippability of the creams was determined by comparing the average watt increase in stiffness per second of whipping time.

The following substances were added in varying amounts up to 0.6 percent to cream before pasteurization: Kraftogen, dehydrated sodium caseinate, Dariloid, gelatin, vegetable gelatin, dehydrated egg albumin, and dehydrated egg yolk. Only three of these substances — Dariloid, gelatin, and vegetable gelatin — increased the viscosity of the cream enough to be of any significance. Dehydrated egg albumen and yolk, Kraftogen, Dariloid, and gelatin slightly decreased whipping ability, while sodium caseinate and vegetable gelatin slightly increased the whippability of the creams. All of the substances decreased the overrun, except Kraftogen and sodium caseinate, which had no noticeable effect. The serum drainage from whipped cream that had stood for 24 hours was practically eliminated by the use of 0.4 percent Dariloid, 0.3 percent gelatin, or 0.4 percent vegetable gelatin, while the other substances had no marked effect. All of the substances added to the cream had a tendency to decrease the percentage of fat in the drainage, except the egg yolk, which had no effect, and the egg albumin, which increased the loss of fat in the serum.

The effect of amount of sugar and time of adding it was studied. The addition of 10 percent of sugar appeared to give sufficient sweetness to the whipped cream. Before pasteurization and immediately before whipping are the least desirable times for adding the sugar from the standpoint of whipping time, overrun, and amount of drainage. Sugar may be added any time after the first minute of whipping without any serious detrimental effects.

Increasing the percentage of serum solids from 6.3 to 11 percent, at 1 percent intervals, by the use of skim milk powder and condensed skim milk decreased the whippability of the cream and had a slight tendency to decrease overrun and drainage. The viscosity of the cream increased as the serum solids content was raised.

The effect of initially aging pasteurized cream for four hours at the following temperatures was studied: 50°, 68°, 86°, and 104°F. As the initial aging temperature was raised, the whippability of the cream decreased and the overrun was variable. The amout of drainage increased only for the 86° and 104° initial aging temperatures, and only the 104° temperature caused an increase in viscosity.

Reconstructed cream made by pumping butter and skim milk through a hand homogenizer did not compare favorably with ordinary cream in whipping ability.

The source of protein in the feed, whether vegetable or animal, had no effect on the whipping ability of the cream.

A Study of the Changes that Occur in the Storage of Frozen Sweet Cream. (H. G. Lindquist.) Studies were continued on the freezing and storing of cream in an attempt to find some method which would prevent the cream from oiling off. No treatment thus far studied has prevented the fat from oiling off when the cream is thawed out and pasteurized. The work will be continued.

Vitamin C Content of Orange Flavored Drinks. (M. J. Mack, in cooperation with C. R. Fellers, Horticultural Manufactures.) A relatively new development is the sale of orange flavored drinks by milk dealers. During the past year the sale of these drinks by dairymen has developed into an important side line. Many dairymen advertise them as rich sources of vitamin C. Since no published information on the nutritive value of these so-called orange drinks is available, the present study was undertaken. Both animal assay and titrametric determination of ascorbic acid by the Tillmans' method were used. The iodine reduction method was also used as a control for comparative purposes. Ten different products were examined, most of them several times. The antiscorbutic potency (protective level for guinea pigs) varied from 6 to over 100 grams, with an average of approximately 15 grams. Fresh orange juice has a protective level of 1.5 grams. That is, most of these so-called orange drinks are poor sources of vitamin C, and the best one contained only one-fourth as much of this vitamin as orange juice. The obvious conclusion is that most of the orange drinks should not be substituted in the diet for fruits as sources of vitamin C.

A Study of the Comparative Efficiency of Electrically Operated Tanks versus Ice in the Cooling of Milk. (J. H. Frandsen.) Work is in progress with the new types of tanks on the market this year.

A Study of the Possibilities of Milk, Cream, and Plastic Cream in the Development of New Products such as Combinations with Honey, Fruits, Cheese, and other Flavors of Various Kinds. (J. H. Frandsen.) Work under this project is being continued, special attention being given to a study of the combinations of certain cheeses and other highly flavored products with plastic cream.

The Quinhydrone Electrode in the Dairy Laboratory. (W. S. Mueller.) This project will be continued by making a study of the glass electrode for determining the pH value of dairy washing solutions. The purpose of this study is to find out whether there is a relation between the pH value as determined by the glass electrode method and the sterilizing property of the solution.

DEPARTMENT OF ECONOMICS

Alexander E. Cance in Charge

A Study of Adjustments in Farming by Type-of-Farming Areas, from the Standpoint of Agricultural Adjustment and Planning, Including Soil Conservation. (David Rozman in cooperation with the Department of Agricultural Economics and Farm Management.) This project was initiated last spring at the request of the Bureau of Agricultural Economics and the Agricultural Adjustment Administration of the United States Department of Agriculture and was carried out in cooperation with farm management specialists of the department.

The main objectives of the project were:

(1) To differentiate the agriculture of the State into type-of-farming areas having similar conditions of soils, crop and livestock systems and farm practices.

(2) To assemble, coordinate and interpret existing data and judgment of agricultural specialists, in order to determine the nature and extent of desirable adjustments in farming in the different type-of-farming areas within the State from the standpoint of good farm management practice and conservation of agricultural resources.

(3) To determine the probable change in terms of acreage and volume of crop and livestock production, if the adjustments indicated as desirable were carried out, and to determine their probable effect on farm income.

In order to present recommendations to the Agricultural Adjustment Administration in conformity with these objectives the following work was carried out:

(1) Locating and mapping out different types of farms in cooperation with county agricultural agents and agricultural specialists.

(2) Land classification of the State on the basis of the United States Soil Survey and information obtained from county agents, agronomists, and agricultural specialists.

(3) Analysis by type-of-farming areas of farm management records available at the College and those collected in field work during the summer.

(4) Historical charts and graphs indicating by counties for a period of 50 years the trend in production of various crops, number of livestock, and land utilization.

As a result of the examination of all the assembled material and consultation with college specialists in various lines of agricultural production, recommendations were presented last fall to the Agricultural Adjustment Administration as to desirable and anticipated changes in the State in the volume of crop and livestock production and land utilization by type-of-farming areas, in the next five years.

Since in Massachusetts there is no soil erosion or soil fertility problem of consequence, recommendations made for various adjustments were based primarily upon a consideration of sound farm management practices.

With regard to two major agricultural industries in Massachusetts, dairying and poultry raising, it was anticipated that there would be a moderate increase both in the number of livestock and in the volume of production in the 5-year period ending in 1940.

While this project is now completed as far as the agreement with the United States Department of Agriculture is concerned, some work on it is still being carried out in completing and refining the material that was collected in the process of investigation.

Decentralization of Industry and Part-Time Farming in Massachusetts. (David Rozman.) The primary objective of this project was to determine the extent to which the location of industrial plants in smaller communities in Massachusetts has been productive of a combined use of labor in industry and agriculture. Accordingly a general survey of all industries was made in towns and cities of less than 10,000 population. In two towns, Charlton and Winchendon, a study was made of comparative standards of living of workers in part-time farming and those outside of it. The field work has now been extended into several other towns to obtain information on the economic and social aspects involved in the decentralization of industry.

DEPARTMENT OF ENTOMOLOGY

A. I. Bourne in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne, and W. D. Whitcomb, Waltham.)

Oil Sprays for Dormant Applications. The winter of 1934–35 was marked by very low temperatures. The amount of damage caused was not so extensive as in the previous year since the extreme periods were of comparatively short duration. In many orchards trees on the way to recovery from the winter injury of the previous year were again severely checked; and a few growers, fearing that the use of oils would aggravate this condition, omitted them from their spray program. No cases of oil injury were reported, however, where oil sprays had been properly applied in the spring, although rather serious damage was caused in at least one orchard following an application of oil spray in late fall.

Red mite infestation in the college orchard was approximately normal, but uneven. In the test blocks the overwintering eggs were moderately abundant so that differences in effectiveness of the various sprays were pronounced.

The leading brands of standard commercial oil sprays again showed a very high degree of control, and the number of young mites appearing on sprayed trees was insignificant.

Two new products were tested. Dendrine, a product of the Carbolineum Wood Preserving Company, is a light-bodied, readily pourable material that mixed readily with water, allowed excellent coverage, and was a good indicator. Rawleigh's Dip and Disinfectant, a cresol-oil combination which also mixed readily with water, possessed excellent spreading qualities. These were used in delayed dormant application at temperatures ranging from 45° to 48°F. and caused no trace of injury. Results were as follows:

Treatments	Number of Mites per 100 Leaf Clusters	Percentage of Clusters Free from Mites	Average Number of Mites per Leaf	Percentage of Control
Dendrine	1,248	72	1.8	79.2
Rawleigh's Dip	2,732	60	4	54.5
Check (unsprayed)	6,000	10	10	—

Three tar washes and three commercial tar oil and mineral oil combinations were applied as dormant sprays in a block of young apples. None of these sprays caused any injury nor was any delay noted in bud development. These results coincided with our experience with similar sprays in 1934 and, inasmuch as they followed two winters marked by periods of extremely low temperatures, indicate that oil sprays of this type can be used with safety in Massachusetts orchards. This was confirmed by the experience of commerical growers who applied such oil sprays. No opportunity was given to measure their effectiveness against plant lice eggs because of the relative scarcity of eggs in the college orchard and the heavy winter mortality of the few eggs that were present.

Spray Materials for the Control of Gladiolus Thrips. A study of the control of gladiolus thrips in the summer of 1935 was along two principal lines.

1. Comparison of spray materials. Several stomach poisons including lead arsenate, calcium arsenate, manganese arsenate, barium fluosilicate, sodium aluminum fluoride, and a mixture of calcium arsenate and arsenite were tested. These materials were used in combination with molasses alone and with molasses and various wetting agents. The tests included the quality of the

suspension, wetting and spreading power, injury to plant, and weight of corms produced. While the results cannot be accepted without reservation, due to the fact that the materials were applied to assorted varieties, they indicate that all of these treatments reduced the average weight per corm as compared with the unsprayed checks. Inasmuch as the infestation of thrips in these plots was light, the factor of thrips injury can be dismissed in this comparison.

Of the various contact poisons that were used, including Black Leaf 40, pyrethrum, derris (two brands) and aliphatic thiocyanates (Lethane 420), derris and Lethane seemed to be superior to the others and were approximately equal in killing value.

2. Varietal differences in susceptibility to thrips attack. Several authors have noted more or less difference in thrips injury to different varieties of gladiolus. One theory holds that the color of the plant masks the injury; another, that some difference in the plant itself favors the development of a large number of thrips.

Observations were made on a large number of varieties. Damage to leaves, buds and flowers was noted. The population was noted by counting the number of thrips in the buds. The heaviest damage occurred to a purple variety and the lightest to a white. Data would indicate, however, that the color has little to do with the abundance of thrips. One pink variety was noted to have an average population of 8.5 thrips per bud, whereas another similar pink had an average of 55.3 thrips per bud.

Further evidence was secured during the summer that in Massachusetts the gladiolus thrips overwinters only on corms. Gladiolus fields immediately adjacent to areas where gladiolus had been grown the previous year and seriously damaged by thrips, showed no serious infestation at the time the fields were visited in mid-August. These fields showed only a very light and scattering infestation and no commercial damage. In all cases the corms had been treated during the winter of 1934–35.

Substitutes for Lime-sulfur in Summer Sprays for Orchards. These tests were continued in cooperation with the Department of Pomology. The studies were chiefly confined to a combination of 300-mesh sulfur and wetting agent; a combination of dry lime-sulfur and flotation, each used at half strength; various strengths of dry lime-sulfur; and Kolofog with a colloidal spreader and lime to prevent the blotching of fruit and to overcome the extreme persistence characteristic of that material. These were used in the calyx and four cover sprays following. Lead arsenate was used in all tests: 4 lbs. per 100 gals. in the calyx, 1st and 2d cover sprays; 3 lbs. per 100 gals. in the 3d cover spray; and 2 lbs. per 100 gals. in the 4th cover.

No injury to foliage nor russeting of fruit was noted following any combination of wettable sulfur or of 300-mesh sulfur and wetting agent. Dry lime-sulfur at the higher strengths caused slight burn to foliage of Baldwin, Greening, and King and a faint trace on McIntosh leaves. McIntosh fruit also showed a slight amount of russeting. No record was made of the Baldwin crop since it was too light and uneven. The degree of control from the use of these sprays was measured on McIntosh. Results are as follows:

Treatment	Dosage per 100 gals.	Percentage of Clean Fruit	Percentage of Fruit Showing Injury from—		
			Curculio	Codling Moth	Scab
Aresket	6¼ oz.	68.4	3.2	1.0	22
300-mesh sulfur	12 lbs.				
Dry lime-sulfur	4 lbs.	84.5	6.8	3.4	1.5
Flotation sulfur	2½ lbs.				
Dry lime-sulfur	6¼ lbs.	88.7	1.0	0.9	5
Dry lime-sulfur	8 lbs.	92.8	1.9	T	0.5
Kolofog	6 lbs.	38.4	9.1	3.6	57
Fluxit	1 lb.				
*Lime	6 lbs.				
Sulcoloid	5 lbs.	90.9	1.5	1.9	2.2
†Lime	5 lbs.				
Check (unsprayed)		.6	37.7	15.2	95.8

*Added in 3d and 4th Cover Sprays.
†Added in Calyx and 1st Cover Sprays.

Scab proved to be difficult to control in 1935 so that all treatments were subjected to great difficulties and few, if any, gave as good results as in more normal seasons. Accurate timing of the sprays in connection with scab development was essential. This development varied in different blocks and caused greater variation in control from the same material in different blocks than between different materials in the same block. In the tests reported above, considerable scab was present on trees sprayed with the Kolofog–Fluxit–lime mixture, yet in another block of the college orchard this same combination of the same dosage held scab to 0.6 percent injury and showed 91.7 percent clean fruit.

Control of White Apple Leafhopper with New Pyrethrum and Pyrethrum–Nicotine Sprays This Department cooperated with the Crop Protection Institute in tests with two of their newly developed pyrethrum products for the control of the second brood of white apple leafhopper in several commercial orchards. The products, designated DX75 (pyrethrum) and DX57 (pyrethrum–nicotine), were applied at a dilution of 1 pint — 100 gallons of water. One application of these materials in one commercial orchard reduced the average infestation from 12 hoppers per leaf to 0.7 on Baldwin, a 95–97 percent reduction. In a second orchard the hopper infestation on McIntosh was reduced from 4.3 per leaf to 0.12, approximately 97 percent control. The results in all the orchards were uniformly satisfactory. Growers found none of the objectionable features of heavy nicotine applications in using these materials. They were applied in several tests on cloudy days and at low temperatures, in some cases during a light rain — conditions in which nicotine sprays would be out of the question, yet the effectiveness of these DX sprays was not materially lessened. They show excellent promise.

Control of Striped Cucumber Beetle with Derris and Pyrethrum Dusts. Summer squash and cantaloupe at the Waltham Field Station were dusted to prevent injury by the striped cucumber beetle. The dusts included two commercial derris mixtures containing .55 percent rotenone, homemade mixtures of derris and clay containing .6 percent rotenone with and without 40 percent sulfur, a 30–70 pyrethrum–clay mixture, and a 10–20–70 calcium arsenate–monohydrated copper sulfate–lime dust. All of these dusts gave satisfactory protection to the plants without causing any apparent injury from their application. It was necessary to apply the dusts five times beginning when the beetles first appeared in moderate numbers.

As a result of two seasons' experiments, it is apparent that during the first month of the growing season dust applications are necessary (1) whenever the beetles become abundant, (2) when two inches or more of unprotected new growth have been made, and (3) after each heavy rain especially when followed by warm clear weather. Such conditions are so dependent on the weather that it is practically impossible to determine in advance the number and time of the applications necessary for satisfactory control, but it seems probable that at least five applications will be required.

Control of the Squash Vine Borer. In 1935, at the Waltham Field Station, the average infestation of untreated Hubbard squash vines was found to be 6.5 borers per plant.

Four sprays of 1 percent summer oil emulsion and 40 percent nicotine sulfate 1–500 applied at weekly intervals beginning July 1 reduced this infestation to 0.84 borers per plant as compared to an average of 1.44 borers in vines sprayed with the standard treatment of 40 percent nicotine sulfate 1–250. A commercial spray of thiocyanate diluted 1–400 was comparatively ineffective.

The outstanding result of this experiment, however, is the good control obtained from four applications of derris–clay dust containing .6 percent rotenone. Due to the difficulty in operating a spray machine in squash fields, dust applications are more practical in many plantings. Furthermore, derris–clay dust is an effective treatment for the contol of the striped cucumber beetle earlier in the season and the continued use of the same material for borer control has many practical advantages.

Control of Cabbage Maggot with Mercury Compounds. In the experimental planting, 100 percent of the untreated cabbage plants were infested by cabbage maggots and 81.33 percent were either killed or so badly injured that they were worthless. In adjacent rows corrosive sublimate solution (1 ounce in 10 gallons of water) applied when the maggot eggs were first found and repeated one week later gave 100 percent protection from moderate or severe injury and produced 86 percent large or medium-sized heads. One treatment with this material applied one week after eggs were found gave 94 percent protection and was slightly more effective than a single treatment made as soon as the eggs were found.

Two applications of a 4 percent calomel–gypsum dust made early in the period of maggot activity gave about 75 percent protection, but one treatment or two late treatments were ineffective.

A new method of treating cabbage seedlings gave promising results when tried for the first time. This consists of shaking or rolling the plants as they are taken from the seedbed in a calomel–gypsum dust until the roots and stems are thoroughly coated. Dusts containing 50 percent and 20 percent calomel applied in this way gave 79 percent and 73 percent protection respectively, and the plants made good growth; but dusts containing 4 percent and 8 percent calomel were much less effective. Since no dust is wasted and later treatments are not necessary, this method seems to have several practical advantages.

Control of Codling Moth with Nicotine Sprays. Two blocks of McIntosh apples at Littleton, Massachusetts, which were heavily infested by the codling moth in 1934 were sprayed: one with a commercial preparation of soluble and insoluble nicotine, and the other with 40 percent nicotine sulfate plus a sulfur soap and bentonite sulfur. One application of these materials in addition to the regular schedule was made July 1 by the owner.

In the block sprayed with the soluble and insoluble nicotine compound, the examination of 15,283 apples showed 6.31 percent stung and 2.64 percent wormy; and in the block sprayed with the nicotine sulfate–sulfur soap combination 2.58 percent and 1.44 percent of the 5,265 apples were stung and wormy respectively. However, only 0.40 percent and 0.33 percent of the harvested apples were wormy, and this is considered excellent control. Most of the worms were in the dropped fruit, there being 11.22 percent more stung and wormy windfall apples in the block sprayed with the nicotine sulfate–sulfur soap combination than in the block sprayed with the nicotine compound. Although these figures favor the latter treatment, the differences are not sufficiently conclusive to offset other factors such as fewer apples, more open trees permitting better coverage, and the addition of bentonite sulfur to the nicotine sulfate spray.

Control of Onion Thrips. (A. L. Bourne.) Conditions during late spring and early summer were unfavorable for onion thrips. The insects were late in appearing and their development was slow. At the peak of their seasonal abundance their numbers were insignificant while the cool weather and frequent rains stimulated the onion plants to make rapid growth, so that little or no injury resulted. Unfortunately for the crop, these weather conditions favored the development of blast, which first appeared about the third week of July and developed rapidly, so that by early August it was present very generally throughout the Valley, and in most of the fields the plants were dying down rapidly.

The most promising of the resistant varieties of onions in the tests of 1934 were selected for further study, and again consistently showed fewer thrips per plant than did the Danvers Yellow Globe, the standard variety grown in the Valley, although the differences were not so marked as in the previous year because of the comparative scarcity of thrips. The average number of thrips per plant is recorded in the following table.

Date	Average Number of Thrips per Plant			
	Danvers	Winegar	Harris	Utah
June 24	0.2	0.2	0.6	0.2
July 1	0.8	0.7	0.6	1
9	5.1	2	1.9	2.5
15	13.6	6	8	6
22	15.4*	4.5	6	5.6
30	20.8†	5	6.8	4.9
August 5	5.5	7.2	6.6	10.4
12	5.3	14.4	9.2	17.8
19	‡	29.6	‡	30.7

*Blast began to appear.

†Plants dying rapidly.

‡Plants down.

It should be noted that the three resistant varieties showed a very light infestation throughout the season. The rapid rise in thrips population on these varieties occurred after blast had killed the plants of the Danvers variety and the thrips had migrated into these plots. The Winegar plots located nearest the Danvers received the greater part of this migration.

The fungous disease found to be attacking thrips in previous seasons was present but not at all abundant. The relative scarcity of thrips and the premature death of the plants early in August due to blast gave little opportunity for its development.

The Spray Residue Problem. (A. I. Bourne.) The limit of tolerance on lead was again reduced for the shipping season of 1935. With the assurance that annual reductions will be made until the recognized minimum tolerance of .014 grains per pound for lead residue is reached, the problem is annually becoming more acute.

Readjustments were made in the spray schedule recommended for Massachusetts orchards. Emphasis was laid on lessening the dosage of lead arsenate in the late summer sprays, particularly on early and mid-season varieties. Growers were urged to substitute a dust schedule for the late cover sprays where possible. Curtailment of funds prevented the cooperation by the State office of the Federal Food and Drug Administration in the analysis of fruit for lead and arsenic residue. Necessary readjustments due to transfer of this work to the station chemists have delayed the work of analysis so that the figures are not yet available.

Experiments with possible substitutes for the standard lead arsenate were centered chiefly upon a calcium arsenate and a specially prepared lead arsenate. Calcium arsenate automatically eliminates the lead residue problem which offers the major difficulty. Practically all brands of calcium arsenate, however, have been found to seriously injure apple foliage and are apt to russet fruit. The particular brand used in our tests, a product of the Niagara Sprayer and Chemical Company under the trade name Calrite, has for two successive seasons been used in a complete schedule on McIntosh and Baldwin without causing either foliage injury or russeting of fruit. In the tests of 1934 this did not prove as effective against curculio and codling moth as did lead arsenate. In 1935 this material was given increased adhesiveness by the addition of a colloidal spreader and proved much more effective, as shown in the following table.

Material	Percentage of clean fruit	Percentage of Fruit Showing Injury from—		
		Curculio	Codling Moth	Scab
Calrite and Fluxit	89.7	Trace	1.4	4.5
Lead arsenate	91.7	1.5	1.5	.6

Both arsenicals were used in combination with the same fungicide. The amount of injury from scab was undoubtedly due to the materials used to increase the adhesiveness of the calcium arsenate. It is significant, however, that both the major insect pests were satisfactorily controlled.

A specially prepared type of lead arsenate which is being developed by the Crop Protection Institute was compared with standard lead arsenate. One of the college blocks was divided so that one-half was sprayed with each material and results were checked at harvest on three varieties: Ben Davis, a variety which russets easily; Rhode Island Greening; and McIntosh. The results are as follows:

Variety	Material	Percentage of Clean Fruit	Percentage of Fruit Showing Injury from — Curculio	Codling Moth	Scab
McIntosh	Special lead arsenate	91	1.7	1.8	Trace
	Standard lead arsenate	84.3	1.4	1.4	10.6
Ben Davis	Special lead arsenate	90	5.5	2.1	....
	Standard lead arsenate	80.0	13.6	3.2	....
R. I. Greening	Special lead arsenate	93.5	0.7	3.5	....
	Standard lead arsenate	93.2	2.9	1	Trace

Considerable russeting was noted in Ben Davis fruit sprayed with the standard lead arsenate. The object of such improvement in lead arsenate would be a greater control of codling moth in the early sprays, giving the main emphasis in the late applications upon apple maggot, which has been shown to be controllable by a weaker dosage of the arsenical or by dust applications.

Apple Maggot Control. (A. I. Bourne.) The adult flies were on the whole less abundant than normal and appeared 7 to 10 days later than usual. In most orchards the pest was much less prevalent than in former seasons except where treated orchards were in close proximity to neglected trees. In the areas under observation, the benefit from the removal of neglected trees in 1933 was becoming obvious, and control of the pest was much less difficult. The wholesale removal of neglected trees created a serious problem for the year following their destruction. Fruit from such trees had been in most cases badly riddled by maggot the previous summer and this led to the appearance of thousands of flies which migrated to the nearest trees, usually commercial orchards. It was particularly essential, therefore, that a thorough control program be followed to give protection against this heavy infestation, and it was noted that where a complete spray program was followed in 1934 the problem of control was much simpler in 1935. In general, except where orchards were inadequately sprayed in 1934 or where the problem was complicated by neglected trees still remaining adjacent to orchards, the recommended spray program gave satisfactory control.

Additional data on the influence of soil conditions and of exposure upon the appearance of flies were secured by Professor Whitcomb at Waltham. These are as follows:

Date of Emergence of Apple Maggot Flies, Waltham

	In Sun		In Shade	
	Cultivated	Sod	Cultivated	Sod
		Light Soil		
1st fly	June 26	July 4	July 10	July 13
25% flies	July 16	July 16	July 20	July 22
50% flies	July 18	July 20	July 24	July 23
75% flies	July 21	July 24	July 29	July 24
		Heavy Soil		
1st fly	July 4	July 12	July 14	July 17
25% flies	July 17	July 21	July 21	July 24
50% flies	July 20	July 24	July 26	July 28
75% flies	July 25	July 29	July 30	Aug. 3

The emergence in 1935 was 17 percent less than in 1934. In general, in these tests, flies emerged from 3 to 7 days later than in 1934 under similar conditions of soil and exposure. The differences appeared to be greater in the beginning of fly emergence.

Introduction of Parasites of Oriental Fruit Moth in Peach Orchards. (A. I. Bourne.) The winter of 1934–35, while not so severe as the previous one, was marked by several periods of low temperature so that in most sections of the State the fruit buds were killed. In many orchards trees weakened by winter injury the previous year were killed outright. The oriental fruit moth was greatly reduced in numbers and as a result of the severe winter and failure to find fruit was nearly wiped out in many orchards. In view of this scarcity, no new introductions of *Macrocentrus* parasites were made although some growers in the southern part of the State purchased and released egg parasites. Midseason collections of infested twigs showed some recovery of parasites, indicating that *Macrocentrus* had survived the severe winter and under more favorable conditions could undoubtedly establish itself successfully.

Potato Spraying Experiments. (A. I. Bourne.) In general potato flea beetles and leafhoppers were of apparently normal abundance. Leafhoppers began to be prominent in early July and continued throughout August, the hot, dry weather of late summer favoring their development. Potato aphids were less abundant than usual since weather conditions during early summer were unfavorable for their rapid increase. The Colorado potato beetle was very scarce and its damage was negligible. Flea beetles and leafhoppers, however, caused more injury than all other insects or diseases combined and poorly sprayed fields suffered severely.

Three rotenone compounds, Ku-ba-tox, Cubor and Derrisol; a barium fluosilicate compound, Dutox; and a calcium arsenate, Calrite, were used in field tests the past season. All were combined with a 5–5–50 Bordeaux mixture, and 14 applications were made at 7-day intervals from June 13 to September 11. All tests were conducted on the standard variety, Green Mountain.

The plants in the unsprayed check plots were badly riddled by flea beetles and browned by leafhoppers and were practically all dead by the last of July. The plants in the sprayed plots were thrifty and green until killed by frost on October 9. The unsprayed checks yielded 179 bushels per acre while the average yield in the sprayed plots was over 430 bushels per acre.

Laboratory tests of the effect of the various sprays upon flea beetles gave the following results.

Material	Percentage of Flea Beetles dead after —	
	40 hours	62 hours
Bordeaux mixture (5–5–50)	4	80
*Ku-ba-tox	33	100
*Cubor	38	100
*Derrisol	78	95
*Calrite	30	75
*Dutox	28	55

*Combined with Bordeaux 5–5–50.

The rotenone products were all very effective and fully as rapid in their action as Calrite. The results given by Dutox were rather unexpected since this material in dust form has given a satisfactory control against flea beetles on tobacco.

Weekly records of flea beetle damage were made in each plot throughout the season. These are summarized in the following table.

Material	Number of Punctures per Leaf Cluster		
	Maximum	Minimum	Average for season
Bordeaux mixture (5–5–50)	444	35	143
*Ku-ba-tox	461	43	151
*Cubor	229	24	110
*Derrisol	207	56	101
*Calrite	204	7	82
*Dutox	317	58	135

*Combined with Bordeaux 5–5–50.

The addition of calcium arsenate (Calrite) to Bordeaux mixture materially reduced the flea beetle injury, and the constant coating of poison on the leaves gave greater protection than did the contact insecticides where sprays were applied at weekly intervals; although as shown by laboratory tests and supported by observations in the field, the rotenone combinations were more effective in their immediate kill of the beetles.

Weather conditions were not conducive to high yields. Hot, dry weather from late July to September interfered with the set of tubers so that yields were materially lower than in 1934. The crop throughout western Massachusetts was estimated to have been reduced by about 100 bushels per acre, which was substantially the reduction in the experimental plots. The yield record in the various plots is as follows:

Material	Yield (Bushels per acre)
Bordeaux mixture (5–5–50)	474.56
*Ku-ba-tox	505.48
*Cubor	416.76
*Calrite	404.21
*Derrisol	392.56
*Dutox	381.35

*Combined with Bordeaux 5–5–50.

A slight amount of foliage burn was noted in the Dutox and the Calrite plots. The high yield on the Ku-ba-tox and Cubor plots was believed to be due to leafhopper control by these materials. Their superiority in that respect evidently outweighed the greater effectiveness of the calcium arsenate against flea beetle. Both of these materials gave increased yields over the Bordeaux plots in 1934, and they appear to be valuable adjuncts to Bordeaux mixture where flea beetle and leafhopper are a real problem, with potato aphids a menace in seasons favorable for their development. It is doubtful whether it would be necessary to add the materials to every application, so their use would not materially increase the cost of the season's spraying.

Value of Electric Traps against Orchard Insect Pests. (A. I. Bourne.) Beginning April 11, 1935, Professor W. D. Whitcomb operated two electrocutor traps in a large rose house at Thos. Roland, Inc., Revere, where a light infestation of the rose leaf roller (*Platynota stultana*, Wals.) was present. These traps were hung from ropes at about 10 feet from the ground and were located about 50 feet on each side of a center walk. The traps were equipped with 100-watt lamps: one a clear glass bulb, and the other a blue glass bulb giving a white light (daylight blue.) The bulbs were alternated at each examination so that any difference in attractiveness of colors would not be influenced by location. On the first night the lights were lit from dark until midnight, but thereafter they were lit throughout the night. Observations were made once each week.

In the period between April 18 and May 29 while the lights were in operation, 801 moths, or 58 percent of the total, were collected in the trap with the clear white bulb; while the trap containing the daylight blue bulb attracted 576 moths, or 42 percent of the total collection.

In addition to the leaf roller moths, a large number of Dascyllid beetles of the genus *Ptilodactyla* were collected in the traps. These beetles were identified by two different authorities as *P. serricollis* Say and *P. exotica* Chp., but no evidence that they were seriously damaging the roses was observed.

During the summer of 1935 the orchard light trap experiment, begun in 1934 in the Bay Road orchard in South Amherst, was continued with the New England Rural Electrification Committee and the Western Massachusetts Counties' Electric Light and Power Company again cooperating with the Massachusetts Agricultural Experiment Station. The work was made possible through support of personnel by ERA funds. Eight light traps were used in the same location as last year.

The primary purpose, codling moth control, was again pursued in order that comparison might be made with last year's results. However, the development and activity of other pests, as well as beneficial and harmless insects were followed since each insect caught was counted and classified. Beginning August 1, new lights of different colors were tested and compared.

The efficiency of the water-pan traps was increased in two ways: (1) by placing a film of oil on the water in the pans, and (2) by raising the bulbs approximately 5 inches higher than last year so that the lower parts of the trees were lighted as well as the upper. In 1934 the water-pan traps caught 20 percent of the total whereas in 1935 they caught 37 percent, an increase of 85 percent. This increase apparently resulted from the changes mentioned above.

In order to check the relative efficiency of the four electrocutor traps the following method was used. For a period of 10 days, July 12 through July 22, the electrocutor traps caught the following numbers of insects: No. 1, 3576; No. 2, 2,122; No. 3, 3,350; No. 4, 3,822. Using the average catch per trap, 3,216.5, as a standard (equalling 100), the indices for the four traps are: No. 1, 111; No. 2, 66; No. 3, 78; No. 4, 118. By the same method, the indices for the water-pan traps are No. 1, 132; No. 2, 72; No. 3, 78: No. 4, 117. From these figures it is evident that the outside traps, i.e., the end traps, caught a far larger number than those between, indicating the advisability, where the traps are to be used on a commercial basis, of placing them in every other tree, at least.

Until August 1, the work for 1935 was similar to that of 1934 and the data secured will be used for checking and comparing with the data secured during 1934. During August, lights of different intensities and colors were used, but since these colors are the components of natural white light, their combined catches may be used as part of the year's catch for comparison with the previous year's total.

A comparison of the numbers of some of the most important groups and species caught in the two years is given in the following table:

	1934	*1935*
Total insects caught	42,857	89,702
Injurious insects	1,037	3,042
Beneficial insects	1,489	826
Codling moth	321	83
Apple tent caterpillar moths	584	1,355
Forest tent caterpillar moths	52	280

Among the other pest insects which were found in the traps during 1935 but not in 1934 were: the common stalk borer, the armyworm, the satin moth, and the northern corn root worm.

Records of the daily catches when compared with the weather conditions show that while rain reduces the number of insects caught during the night of a storm, a peak occurs on the following night. For instance, the heavy rain of July 7 and 8 caused a comparatively small catch for the two nights (1394 and 554), but on the following night, July 9, a marked peak occurred (3,984) and was the largest night's catch for the season even though the temperature was only 72° at 8:30 p. m.

Temperature is the most important single weather factor in governing insect catch in light traps. In the majority of cases a peak in temperature was accompanied by a corresponding peak in the number of insects caught. However, when making such comparisons it must be remembered that a large number of insects with widely varying habits and life histories are being considered and all these insects probably are not influenced in the same way by weather conditions.

Beneficial insects comprised but 0.9 percent of the total number of insects caught as compared with 3.7 percent in 1934. Peaks of emergence concurring with peaks of temperature agree with the theory advanced in last year's work, that temperature has a greater effect upon parasite emergence than on Lepidopterous insects.

In determining the relative efficiency of the various colors of the lights used in the traps, allowance had to be made for the location of the traps, which was an important factor in governing the numbers of insects caught. The traps on the ends of the rows caught nearly twice as many insects as those between them. Collections show that the colors of high frequency (blue and green) are superior to those of low frequency (amber and red.) The total collections show that the blue light attracted the greatest number of insects; the green, second; the amber, third; and the red, the least. In comparison white light was shown to be less satisfactory than the colored, particularly those of high frequency (blue).

Of the insects caught, among the Diptera the families Tipulidae, Culicidae, Bibionidae were most strongly attracted to blue light. Drosophilidae were very strongly attracted to amber light. Among the Lepidoptera but little preference was shown. The Noctuid moths (adults of cutworms) were attracted chiefly to red light and least to blue; while the Pyralidae were strongly attracted to blue and less to amber, green or red light. One species, the codling moth, showed a preference for high frequency colors, notably blue.

The experimental work of 1935 again emphasized the fact that light traps furnish a very accurate index of the emergence rates of insect species and also of their relative numbers from year to year. It was also apparent that insect species show a marked color preference and that for the most part this preference is for the high frequency colors.

Insects Concerned in the Dispersal of Dutch Elm Disease. (W. B. Becker.) A study was made of the present distribution of the elm bark beetles concerned with the spread of the Dutch elm disease. The material which was collected by scouts and supervisors in the State ERA project on this disease formed the basis of this survey. Although not all of the towns in the State were scouted, sufficient material was received from all sections of the State to furnish an accurate working knowledge of the distribution of the beetles likely to be vectors of the Dutch elm disease before it actually enters the State.

Scolytus multistriatus, the species of European elm bark beetle known to transmit the disease, was taken from several towns in Essex, Middlesex, and Plymouth Counties, well outside its previously known range in eastern Massachusetts. Specimens of elm bark and wood from the towns of Westfield and Egremont in western Massachusetts also showed the presence of this species. However there is an infestation of these beetles which centers at the Port of New York and which extends to points in Connecticut and New York State which are quite close to these two towns in western Massachusetts, so it is probable that the beetles spread to Egremont and Westfield from the New York infestation rather than from the infestation surrounding Boston. Altogether forty-seven specimens of elm wood showing *Scolytus multistriatus* infestation were received.

The American elm bark beetle, *Hylurgopinus rufipes*, (a native of this country) which has also been associated with cases of the Dutch elm disease, was found distributed over practically the entire State. One hundred and nineteen specimens of *Hylurgopinus rufipes* were received. A study of the records taken this summer showed that about 40 percent of the bark beetle infestations found were in elm log piles. This information brings out the fact that these beetles breed extensively in elm logs. Therefore any sanitation measures applied to standing trees must also include a clean-up of elm log piles in order to eliminate the places where these bark beetles breed. Recently cut elm logs are especially favorable to attack by the beetles.

The large elm borer, *Saperda tridentata*, and the elm snout beetles, *Magdalis* sp., were often found in the same piece of wood with both of the elm bark beetles mentioned above.

Two hundred and fifty-four specimens of shade tree insects or their injury were received. Two hundred and fourteen of these were elm insects.

Circulars were sent to all the tree wardens in the State calling attention to the seriousness of the damage which is being done to the foliage of our elm trees by the elm leaf beetle, *Galerucella xanthomelaena*. Injury due to this insect can mask the symptoms of the Dutch elm disease if it should happen to be present, thus making scouting for the dread disease inefficient. Trees defoliated by this insect are weakened and thus put into a favorable condition for the breeding purposes of the bark beetles which are known to be capable of transmitting Dutch elm disease.

Life history studies of the American elm bark beetle, *Hylurgopinus rufipes*, were undertaken. Very little has been previously known of its life history and habits. It overwinters abundantly in Amherst, in short tunnels which it digs into and through the bark of apparently healthy trees. In the early spring it emerges from these tunnels and in the latter part of May was noticed attacking trap logs which were set out for the purpose. Dying parts of elms were also observed to be attacked. Only one generation of beetles was reared in the field. They began to emerge about the first of August; reached the peak of emergence on August 20; and gradually lessened until the cold weather set in. The fact that *Hylurpoginus rufipes* breeds in dead and dying elms and later attacks apparently healthy elms in which it digs overwinter tunnels makes this beetle especially important as a possible vector of the Dutch elm disease in the event it comes in contact with the disease.

Apple Leaf Curling Midge. (W. D. Whitcomb, Waltham.) The apple leaf curling midge, (*Dasyneura mali* Kieffer) was normally abundant in 1935 in the infested area, although its principal development was confined to two generations as compared to an apparent moderate third and a small fourth generation in other seasons. No definite increase in the known infested area was discovered.

It was determined that pupation in the overwintering cocoons begins with the approach of warm spring weather, and the average pupal period was 9.75 days.

In the orchard, flies of the overwintering generation were abundant from blossom time (about May 20) until June 4. Eggs and newly hatched larvae were plentiful during this same period and mature maggots began to leave the rolled leaves by June 18, with large numbers on June 25 and July 9. Flies of the first generation were abundant from July 12 to July 30. New growth suitable for oviposition was limited at this time but that which was available was thoroughly infested with eggs and young maggots. Mature maggots of this generation migrated from the rolled leaves in large numbers on July 30 and continued for about a month, being especially noticeable on August 6 and 23. Development in September was insignificant.

Positive evidence was secured that migration of mature maggots from rolled leaves is dependent on moisture. Based on precipitation records, at least 3/10 of an inch of rain was necessary to cause a noticeable migration from the leaves.

In 1935, 87.8 percent of the maggots which were collected on July 9 transformed to flies during the current season, but of those collected on July 12 and July 30 only 5.17 percent and 7.89 percent respectively transformed. Since the absence of suitable buds for oviposition in late summer would greatly reduce the population, this ability to hold over is an important factor in the continuation of an infestation.

The number of mature maggots collected under felt bands on the trunk and branches, and on 18 square feet of cloth under the tree, averaged about 1500; but since the cloth covered only about one-fourth of the area under the tree, this indicates that approximately 80 percent of the maggots fall to the ground and 20 percent crawl down the branches.

The addition of 40 percent nicotine sulfate 1–800 to the regular calyx spray reduced the average number of midge eggs from 169.8 per bud where no nicotine was added to 87.6 per bud, and the average number of developing larvae from 278.8 to 202.6 per twig respectively. In both cases, however, the number of infested buds per tree was approximately equal.

Calcium cyanide at the rate of 1 and 2 pounds per 100 square feet, and naphthalene flakes at the rate of 2 and 3 pounds per 100 square feet, applied to the soil under the trees just before fly emergence, reduced the number of flies from 61 to 80 percent but were slightly less effective than similar treatments in 1934.

Experiments indicated that about 90 percent of the maggots which crawl down the trunk of the tree can be collected under 2-inch felt bands and that leather bands are also satisfactory. Corrugated paper bands treated with betanaphthol, when tried late in the season, were not repellent and killed all maggots which entered them.

Laboratory experiments with potted apple trees indicated that spraying with a combination of soluble and insoluble nicotine will reduce the infestation 75 percent or more for four or five days. Application before exposure to infestation is more effective than after exposure. The spray both repels the fly and kills the eggs and newly hatched maggots. Other experiments showed that derris powder in water at the rate of 6 pounds in 100 gallons plus a neutral spreader is effective for several days.

A suggested schedule of treatments which should greatly reduce the abundance of the midge and prevent its development into a serious pest is as follows: Cultivation under trees before blossom period; application of 1 pound of calcium cyanide or 2 pounds of naphthalene flakes per tree just before blossom period; addition of nicotine to calyx and first apple maggot sprays; and application of beta-naphthol treated corrugated paper bands to trunks of infested trees about June 15.

Adaptability of Cryptolaemus to Control of Mealybugs in the Greenhouse. (W. D. Whitcomb and Wm. Garland, Waltham.) The use of the ladybird beetle, *Cryptolaemus montrouzieri*, Muls. to control mealybugs in a large commercial gardenia range was continued under the supervision of the writer. As in 1934 the activity of a large second generation of *Cryptolaemus* larvae in late May and early June together with favorable temperatures not only controlled the mealybugs but practically eliminated them from the aerial parts of the plants. It was found, however, that a small number of mealybugs were living at the base of the gardenia stems protected by soil and mulch, and that the ladybird beetle larvae would not burrow and kill them in such places. Aided by ants, these surviving mealybugs slowly spread over the plants and built up a slight to moderate infestation during the summer so that the liberation of more beetles in the early fall or the application of artificial control measures was necessary.

Preliminary studies leading toward the development of a method for keeping surplus beetles until needed were unsuccessful but provided some information which will be followed in further experimentation.

Laboratory studies of the citrus mealybug showed that although about one-third more eggs were laid at 80° than at 60°, their activity at the lower temperatures is considerably greater than that of *Cryptolaemus*.

Oviposition studies of *Cryptolaemus* beetles at controlled constant temperatures showed an average of 63 and 61 eggs laid by each female at 80° and 70°F. respectively, but only 24 eggs at 60°. It required 13.7 days for these eggs to hatch at 60°, but incubation was completed in 8.28 and 4.55 days at 70° and 80°F.

The value of these larvae as mealybug destroyers was studied at 60°, 70°, and 80°F. by feeding larvae from birth to prepupal dormancy with as many mealybug eggs as they would eat, and recording that number each day. Of the 66 larvae used in this experiment only 11 were raised to larval maturity and none of them in the 60° cabinet. The average number of mealybug eggs eaten by each larva each day at 60° was 1.74, while the number increased to 8.68 at 70°, and 9.15 at 80°F. The larvae which completed their growth at 80° ate 1427 mealybug eggs or an average of 26.67 per day, and at 70° the total was 1397.8 or 23.23 eggs per day.

From these records it is apparent that both 70° and 80° are favorable temperatures for *Cryptolaemus* activity but that 60° or less so retards their activity that these insects have little or no value for mealybug control.

Naphthalene as a Fumigant for the Control of Greenhouse Insect Pests. (W. D. Whitcomb, Waltham.) A report on previous studies with naphthalene as a greenhouse fumigant has been published as Bulletin 326.

Further work with an electric fumigator in which a fan is combined with a heating unit determined that in the experimental equipment about 20 percent of the naphthalene placed in the trays was vaporized in an average exposure of 6 to 8 hours. Since air can hold only a limited amount of naphthalene vapor, the vaporization of the crystals can be increased within certain limits, (1) by enlarging the air draft capacity of the apparatus, (2) by lengthening the period of exposure, and (3) by raising the air temperature. On the other hand, it was found that when the air draft and the air temperature remained constant, the percentage of naphthalene vaporized in a given length of time decreased as the amount of napthalene crystals was increased.

Experiments with two commercial liquid fumigants containing materials similar to naphthalene indicate that they are very efficient for the control of red spider, and that the mortality following one fumigation is generally greater than from naphthalene. It was also found that these materials could be used satisfactorily at any of the lower temperatures at which greenhouse plants are grown.

Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) In 1935, plum curculio beetles emerged in large numbers during the petal fall period, and consequently the calyx spray was more effective in combating this insect in apples than normally. An extended period of cool wet weather during the normal period of curculio activity made two applications, one just before the rainy period and one just after it, necessary for the best control.

Experimental spraying for timeliness of application at the Waltham Field Station orchard, using lead arsenate and fish oil, showed that the most timely two-spray applications were made June 3 and 15, while the most effective single spray was applied June 7.

The susceptibility of varieties all receiving the same control treatments was as follows: average percentage of apples stung by plum curculio, Gravenstein 25.84; Wealthy 16.35; Baldwin 10.12; and McIntosh 6.51.

Influence of Temperature on Development and Control of Red Spider. (W. D. Whitcomb, Waltham.) Studies of the influence of temperature on the effectiveness of spray materials for controlling the red spider were continued in constant temperature cabinets at 60°, 70°, and 80°F.

Miscible pine oil, an ingredient in several of the newer sprays, gave a very low kill of red spider and apparently adds very little to the toxicity of the materials with which it is combined. The effect of temperature was irregular, but slightly better control was obtained at 80°F.

A concentrated pyrethrum paste containing 1.95 percent pyrethrins plus .5 percent of neutral soap killed about 30 percent of the spiders and the majority of the dead spiders apparently were killed by the soap. Another pyrethrum extract in acetone (2.15 percent pyrethrins) diluted 1-200 was only slightly effective, and the mortality was not increased by the addition of pine oil 1–400.

When pyrethrum was combined with derris or cube extractives in alcohol an excellent mortality resulted. With this commercial product the mortality increased about 5 percent with each increase of 10 degrees in temperature, and increased about 10 percent when the dilution was raised from 1–400 to 1–200. Another commercial product containing 1.5 percent rotenone in acetone gave good control at 80°F. but showed a 20 percent decrease in mortality at 60°.

Pine tar soap in the liquid form was only moderately effective when diluted at .5, 1, and 2 percent. In the flake form a solution prepared at the rate of 8 pounds in 100 gallons was very effective but lesser amounts were only moderately so. In most of these trials the effectiveness of the soap for red spider control was greater at 60°F. than at 80°.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920, Chapter 94)
Seed Control (General Laws, 1927, Chapter 94)
Dairy Law (General Laws, 1920, Chapter 94)
Advanced Registry Testing
Miscellaneous Work

Feed Control. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski, F. A. McLaughlin, J. T. Howard.) During the fiscal year, 1,651 samples of feeding stuffs were officially collected and examined in the control laboratories. The results show that at least 95 percent of the samples collected varied less than 1 percent from stated guarantees in protein, fat and fiber content. The gross receipts from the registration of feeding stuffs in 1935 (calendar year) were $21,400, derived from 1,070 brands at $20 each.

Seed Control. (P. H. Smith, F. A. McLaughlin, Olive M. Hoefle.) From October 1, 1934, to October 1, 1935, the seed laboratory analyzed 1,356 samples of seed, of which 743 were collected by the State Commissioner of Agriculture and 408 sent in by dealers and farmers. Tests for viability were also made on 205 ingredients found in the 41 Special Mixtures.

Classification of these analyses is shown in the following summary:

	Official Samples	*Non-official Samples*	*Totals*
Purity analysis only	45	47	92
Purity and gemination	209	83	292
Laboratory germination only	489	278	767
Laboratory germination of Special Mixtures*	205		205
			1,356

*Samples germinated as a check on the quality of seed contained in the 41 official samples which, by law, require only the statement of purity.

Field tests to determine trueness to type were conducted in cooperation with the Department of Vegetable Gardening, which tested 207 samples of vegetable seed, all of which were collected and submitted by the State Commissioner of Agriculture.

Dairy Law. (P. H. Smith, J. T. Howard, H. L. Allen.) During the year ending December 1, 1935, 9,226 pieces of Babcock glassware were tested. Condemned glassware consisted of one pipette and 38 cream test bottles. One hundred and thirty-six certificates of proficiency were awarded.

Two hundred and twenty creameries, milk depots and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, four machines were condemned, and repairs were ordered on twelve. Six plants were re-inspected to approve repairs.

Advanced Registry Testing. (P. H. Smith.) Advanced registry testing has been supervised by this department since its beginning in 1902. There are now on yearly test 331 cows located on 40 different farms. This does not include the herd tests where all animals in each herd are placed on test. Of these there are thirty, three of which are supervised by men sent out from this office and twenty-seven by cow-test association supervisors.

Miscellaneous Work. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski.) Numerous analyses have been made for residents of the State and other departments of the college.

Summary of Miscellaneous Work, 1935

Materials sent in:	
Milk and cream, butterfat only	237
Ice cream, for fat	41
Feeds, from farmers and dealers	116
Feeds, from State Institutions	114
For other departments of Experiment Station and College:	
Milk, for butterfat	301
Dry matter, forage crops	553
Complete fodder analyses	30
Dry matter and nitrogen	12

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski, Chemists; J. T. Howard, C. L. Whiting, G. E. Taylor, Sampling Agents; Harry L. Allen, Laboratory Assistant.) Records for the year show that 115 firms have registered for sale in the State of Massachusetts 489 brands of mixed fertilizer and fertilizing materials and 54 brands of agricultural lime and gypsum. Results of analysis show that about 82 percent of the fertilizer brands and 69 percent of the lime brands showed no deficiencies. The gross receipts from the registration of the fertilizer and lime products and from fertilizer tonnage fees for the year 1935 were $14,190.

For ten weeks beginning April 1, three experienced men employed to draw samples for inspection purposes sampled 22,458 sacks or containers, representing 13,178 tons of materials; 1,025 agents were visited. The following summary shows the character of these substances, as well as statistics with reference to their inspection.

	Brands Registered	Brands Collected	Samples Drawn	Number of Analyses	Number of Determinations
Mixed fertilizers	284	304	1,165	416	6,042
Ground bone, tankage and fish	53	51	199	70	426
Nitrogen products, mineral and organic	47	45	216	122	428
Phosphoric acid products	22	21	116	36	154
Potash products	23	23	82	40	110
Dried pulverized natural manures	32	35	138	55	345
Nitrate of potash	6	5	11	6	26
Peat products	6	7	13	9	47
Wood and cotton hull ashes	4	3	9	9	58
Miscellaneous	9	5	12	8	75
Lime products	54	54	117	60	442
Totals	540	553	2,078	831	8,153

During the period July 1, 1934, to July 1, 1935, the tonnage of fertilizer and plant food, and lime products as soil amendments, sold in Massachusetts was as follows:

		Plant Food Elements (Tons)		
	Fertilizer (Tons)	Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	42,912	2,231	3,775	3,048
Unmixed fertilizer chemicals and materials	18,711	1,308	1,670	585
Pulverized natural manures	1,585	33	25	44
Totals	63,208	3,572	5,470	3,677
Lime products (as soil amendments)	25,902			

Full details of the fertilizer and lime inspection will be found in Control Bulletins 81 and 82.

Miscellaneous Analytical and Diagnostic Work. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski.) Chemical studies of a cooperative nature have been carried on, as has been the custom in the past, with the several departments of the institution, Field Station and County Agents. The character and extent of this work is shown in the following summary:

Apple tree leaves	6
Fertilizer and fertilizing materials	9
Experimental crops, magnesium deficiency	47
Manure and synthetic manure	5
Sugar cane fiber	1
Miscellaneous	4

Other chemical work of the department has included service to community organizations, State institutions, and individuals interested in agriculture. This group includes the following materials:

Animal tissue for arsenic	1
Ashes of various kinds	3
Fertilizers and fertilizer chemicals	34
Fungicides	2
Gardenia leaves, normal and abnormal	2
Greenhouse soils (complete analyses)	8
Horse manure, peat as absorbent	1
Hydrated lime	7
Lime waste products and limestone	4
Miscellaneous substances	7
Peat products	5
Refuse by-products	5
Samples used in research on new analytical methods for magnesium	37
Talc for magnesium source	1
Water used on turkey ranch	1

Research work in cooperation with the Association of Official Agricultural Chemists of North America has included modified methods for potash, active water insoluble organic nitrogen, and soluble and available magnesium products used in mixed fertilizers; other services of an executive and advisory nature have also been rendered to this organization as in the past.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) Field Station strains of rust-resistant snapdragons crossed to the various California strains carrying resistance resulted in considerable varied segregation for resistance. The Field Station strain 3413–3 crossed with Florists' Pearl and Shasta of the California group resulted in the most uniform segregation for resistance. The F_2 generation from selected crosses is to be carried on for further selection for bronze, red, and pink types.

The Field Station strains continued to stand up under resistance tests and to breed true in the field. It has been observed for two years that certain of the Station strains are more immune to Verticillium Wilt than others, and very noticeably so when compared to commercial strains. Field plantings have always been made on the same field where rust and wilt have been prevalent for the past four years. Seed which has been received from the California Station where selections have been made for a wilt disease will be planted for comparison with the Field Station strains.

Seed of certain Field Station strains is being grown in quantity for trials with various greenhouse growers; it is hoped that sufficient seed for this purpose will be available in the spring of 1936.

Propagation Studies on Geraniums. (Harold E. White, Waltham.) The same experimental setup was used during 1935 to determine what effect seasonal conditions in the field might have on the rooting of cuttings, and to note whether the maturity of the plant was concerned in successful propagation by taking cutting material in August, September, and October. Approximately two thousand cuttings were taken in August, at least 80 percent of which were lost through stem rot caused by the fungus *Pythium*. Similarly, with the September and October lots of cuttings, heavy losses were experienced because of stem rot. Sterilizing the sand with steam, treatment with potassium permanganate and with bichloride of mercury did not noticeably check the rot. Surface disinfection of the cuttings with potassium permanganate or bichloride of mercury did not seem beneficial.

Examination of the plants in the field revealed that, while cuttings might not show any external symptoms of infection, the vascular system would show a distinct brown discoloration. Cuttings with and without this brown discoloration were placed in sand to root; the normal cuttings showed 8 percent loss from rot as compared to 31 percent where the vascular system was discolored.

The fact that the percentage of rooting varied from 92 to as low as 10 under various propagating conditions, indicates that probably the success or failure of growers in rooting geraniums is due to the absence or presence of stem rot rather than to the degree of maturity of plant material or to propagation methods.

Further work is necessary to determine what practical propagation methods and control measures are most feasible for growers.

Study of the Effect of Plant Nutrients, Soil Reaction, and Light on Gardenias. (Harold E. White, Waltham.) Gardenias produced more flowers per plant under sand plot culture conditions than in soil, irrespective of different levels of nitrogen, phosphorus, and potash. The highest yield per plant in the sand plots was 16 flowers as compared to 10 flowers per plant in soil. When different ratios of nitrogen, phosphorus, and potash were used, there was greater variation in yield between individual soil plots than between sand plots in the same series. Increasing nitrogen, phosphorus or potash did not produce any significant differences in yield.

There was considerable variation in the amount of bud drop in both sand and soil, but in no case was there complete freedom from bud drop under any treatment. The summary of data on bud drop is as follows:

	Bud Drop, Percent	
	Low	*High*
Nitrogen Series:		
Sand	19.31	56.37
Soil	55.84	78.37
Phosphorus Series:		
Sand	16.50	34.67
Soil	24.75	71.11
Potash Series:		
Sand	19.31	51.08
Soil	37.00	90.00

Interveinal chlorosis was very severe on plants in all soil plots which were given calcium nitrate and sodium nitrate as sources of nitrogen and in plots on which one-half of the nitrogen was supplied as calcium nitrate in combination with ammonium sulfate. One soil plot receiving all of its nitrogen from an organic source showed only a trace of chlorosis, while another which was fed with a fertilizer containing sulfur showed no chlorosis. Plots receiving ammonium sulfate as a source of nitrogen did not show chlorosis.

Plants grown in sand and fed with calcium or sodium nitrate as a source of nitrogen showed severe chlorosis; whereas, when one-half the nitrogen was supplied as ammonium sulfate, the chlorosis was reduced to a noticeable degree. Direct inoculation of chlorotic leaves with various chemicals resulted in a response when iron compounds only were used. Plants severely affected with chlorosis did not recover when applications of iron sulfate, sulfur, or ammonium sulfate were made to the soil around such plants. Chlorotic plants placed in soil where all other plants were normal did not recover their green color after an elapse of five months.

Soil pH would not seem to merit the importance that has been attached to it as an indicator for determining the best cultural conditions for gardenias. This may possibly be found to hold true for all those plants classed as having a preference for an acid soil condition. The average pH, taken over a period of six months, varied from 5.0 to 6.0, with chlorosis appearing on plants when the pH at times dropped below 5.0.

Lengthening the day by six hours with 60-watt bulbs, starting in November and continuing until March, had no noticeable effect on recovery from chlorosis, on bud drop, or on production.

A canker disease observed on plants at the Waltham Field Station has been found to be of economic importance in local greenhouses. This disease is to be included in the present studies.

A paper on the gardenia experiments is to be presented at the meetings of the American Society for Horticultural Science in 1935.

Propagation Studies on Gardenias. (Harold E. White, Waltham.) Gardenias rooted equally well whether the nodal cut was made through, above, or below the node. Leaf cuttings root readily, but a bud or eye must be present for normal growth; for, although roots will form, development of shoots does not take place when the entire bud is not present. Potassium permanganate treatment did not seem to hasten rooting, while a .05 molecular solution of cane sugar appeared to increase rooting. The type of rooting medium apparently did not affect rooting: but in a peat and sand mixture, the roots, once they had formed, made more rapid growth than in sand.

A period of six to seven weeks is required for rooting gardenia cuttings. High humidity is an essential condition. An increase of 30 percent in humidity was observed when propagation was carried on under an enclosed frame as compared with the open bench method. The enclosed frame method with a bottom heat of 60° and a humidity of around 80 percent shortened the rooting period about one week.

There was an increase of from 40 to 50 percent in rooting of cuttings taken from sand plots as compared with those from soil plots. This increase may have been due to the fact that the sand plots showed less interveinal chlorosis. Roots on cuttings taken from normal plants were more abundant and vigorous than on cuttings from chlorotic plants.

Gardenia canker was observed on cuttings in the propagating bench of a commercial range, indicating that this disease may be carried over on the cuttings. This condition has not been observed at the Waltham Field Station, probably because the disease, while present, has not been severe this season. Infection of the cutting material is quite possible inasmuch as the practice is to take cuttings near the bottom of the plants where the spores could be splashed up from the soil and from cankers at the base of the plants.

DEPARTMENT OF HOME ECONOMICS

Helen S. Mitchell in Charge

Cause and Control of Nutritional Cataract. (H. S. Mitchell and O. A. Merriam.) The production of nutritional cataract in rats fed on lactose or galactose has been previously demonstrated. In a new series of over 100 animals there was an 85 percent incidence of mature cataract on the 70 percent lactose ration, 100 percent incidence on the 35 percent galactose ration, and none where other carbohydrates were used. A study is now being conducted into the metabolic disturbances involved, other pathological manifestations, and possible means of prevention and cure. So far a mature cataract once formed has never been made to disappear. Certain alterations in the composition of the rations suggest a slight hastening or retarding of cataractous changes. Different strains of rats show variable susceptibility to cataract formation.

This project has presented many difficult problems but offers a promising means of approach in the study of an unsolved human disease which may have a nutritional origin in some cases.

Use of Banana and Milk in Diets for Weight Control. (H. S. Mitchell and G. M. Cook.) This cooperative project sponsored by The United Fruit Company was begun in October, 1935. Low calorie diets which at the same time satisfy hunger are desirable for any reducing regime but especially so in the case of active college students. One part of this study is being made on a group of extremely overweight students, offering them an opportunity to reduce under the guidance of a trained dietitian and affording us a chance to make subjective and objective observations on the group. The dietary regime used consists of fruit and milk, with some minor additions, for breakfast and lunch and a complete dinner of meat and vegetables of low calorie value. Bananas constituted the chief fruit used during one experimental period while other fruits were used during alternate periods.

Another phase of this project has been concerned with a distinctly underweight group of students who have been given supplementary between-meal lunches of bananas and milk in an effort to help them to gain. It is more difficult to maintain the interest and cooperation of this group.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Technological and Nutritional Investigations of New England Apples. (J. A. Clague, C. R. Fellers and W. A. Maclinn.) Ciders made from eight varieties of Massachusetts apples were clarified by both the gelatin-tannin and the Pectinol processes. The ciders were examined for soluble solids, specific gravity, pH, viscosity, total acidity, tannin, pectin, and ash, both before and after clarification.

Roxbury Russet was found to be a very desirable variety to use for the manufacture of cider for beverage purposes. With other varieties better quality would probably be obtained by blending two or more varieties.

Chemical tests showed that clarification by either the gelatin-tannin or the Pectinol process did not appreciably affect the specific gravity, sugar content, or pH of the ciders. Relative viscosity, pectin content, and tannin and coloring matter were, however, most significantly changed by the clarification treatment. The gelatin-tannin method caused a much greater loss of tannin and coloring matter than did the Pectinol process.

A small coil flash pasteurizer was constructed and found to be a satisfactory method of preserving clarified cider.

A study of the manufacture of sparkling cider on a small scale has been started.

A comparison of the 2, 6 dichlorophenolindophenol titration with the iodine titration method on samples of pasteurized clarified and germ-proof filtered cider showed that the iodine titration gave four times as much ascorbic acid (vitamin C) as did the titration with the dye. Neither method showed the presence of a significant amount of vitamin C when cider is compared with some of the foods having a high antiscorbutic value.

Cranberry Investigations. (C. R. Fellers, J. A. Clague, P. D. Isham and Wm. B. Esselen, Jr.) Submergence of the plants on the bog causes an increased rate of respiration in the cranberries and an increase in carbon-dioxide content of the internal atmosphere. It is probable that this increased rate of respiration weakens the cranberry and facilitates fungus invasion. Frosting reduces the rate of respiration. Temperature of storage has a marked effect on keeping quality. Low temperatures slow up all the physiological activities of the fruit and extend the storage life. The carbon-dioxide content and the carbon-dioxide oxygen ratio vary directly with the keeping quality. The carbon-dioxide and oxygen contents of the internal gas vary with the rate of respiration. At high respiratory rates the combustible reserves are soon oxidized and storage life shortened. The carbon-dioxide oxygen ratio may be used to forecast the approximate keeping quality of cranberries for several months in advance.

There is no correlation between catalase activity and respiration of cranberries in cold storage. In general, cranberries show a sharp increase in catalase activity a short time before they begin to show structural breakdown. The potassium permanganate titration method for catalase activity is inaccurate because of interfering substances.

The researches on the isolation and determination of organic acids of the cranberry have been completed and a paper prepared for publication.

Cranberry juices, both raw pressed and heat extracted, have been prepared and made into satisfactory beverages. The yield of raw-pressed juice is 2.5 to 3.0 gallons per barrel (100 lbs.) of cranberries. Cranberry juice may be clarified by means of a pectinase enzyme preparation, Pectinol. A study is being made of cranberry cordials.

Microscopic studies of cranberry sauce show that there is a direct relation between the percentage of microscopic fields showing mold filaments and the actual precentage of decayed cranberries used in manufacturing the sauce. By this means it will be possible to determine with considerable accuracy the actual percentage of spoiled, decayed fruit used in manufacturing sauce.

A bacteriological study of the feces of albino rats has shown that the addition of fresh or dried cranberries to the diet reduces the number of *B. coli* organisms and gas formation in the intestinal tract. A diet containing cranberries tends to lower the pH of the entire intestinal tract, particularly when the basal diet itself is one which promotes a lowered intestinal pH. This evidence indicates that cranberries should have a favorable effect in reducing intestinal putrefaction and bringing about a more tonic condition in the intestinal tract.

The use of the ferric oxide reduction test of Bergeim as a measure of intestinal putrefaction has shown that fresh apples, cranberries, and blueberries significantly reduce intestinal putrefaction.

Tomato Juice Investigations. (C. R. Fellers, W. A. Maclinn and J. A. Clague.) A full report on the vitamin C content of both commercially canned and laboratory-prepared tomato juices has been published in *Jour. Home Econ.*: 27, 447–451. The attempt to use the Tillmans' titration method for the estimation of ascorbic acid in tomato products has not been entirely successful. The work is being continued. The data show that canned tomato juice is an excellent antiscorbutic and may be safely substituted for citrus fruits as a source of vitamin C.

Red Squill Research. (R. E. Buck, E. M. Mills and C. R. Fellers.) Two papers have been published giving the results of this investigation to date (*Ind. Eng. Chem.* 27: 1377–1380; 1497–1499). The value of alcoholic extract prepared by percolation methods as a potent raticide has been fully demonstrated by extensive laboratory and field tests.

Microbiology of Dried Foods. (J. A. Clague in cooperation with the Department of Bacteriology.) The number of microorganisms on dried foods varies from a few thousand per gram as a maximum on dried fruits up to several millions per gram on dried vegetables.

Tests conducted with a small tunnel drier showed that artificial drying effectively eliminated yeasts and materially reduced the numbers of bacteria and molds on dried fruits. Reduction of the numbers of microorganisms on vegetables during the drying process was not so marked as with fruits; in fact dehydration alone did not completely eliminate *Escherichia coli* which was inoculated on the vegetables, although the blanching process was efficient in this respect.

Solid media suggested for a study of dried foods are: plain nutrient agar as recommended in Standard Methods of Water Analysis, and tomato agar for yeasts and molds.

The methods used in the commercial dehydration of foods should produce a safe product, especially when it is considered that most of these foods are cooked before being consumed.

A paper on this study is now in press. (*Food Research* 1: 45–59.)

Nutritive and Technological Studies on Fishery Products. (C. R. Fellers, J. A. Clague, F. P. Griffiths, W. S. Conway Jr., and V. K. Watson.) Additional experiments have confirmed our previous report on the Atlantic whiting as suitable for canning, flaking and chowders. This study will be extended to include further technological and nutritional investigations on this fish.

Part of the study of fish meal in poultry feeding has been published in *Trans. Fisheries Soc.* 64: 293–303.

Bio-assays of mackerel oil showed that the body oil contained about 7 U.S.P. units of vitamin A per gram while the liver oil contained 25 units per gram. The mackerel body oil contained no significant amount of vitamin D, while the liver oil had about 25 U.S.P. units per gram. The mackerel oil when fed to rats with casein or with fat-free mackerel flesh had an apparent toxic effect on the rats.

Nutritional and chemical studies on the sand crab, *Platyonichus ocellatus* and the blue crab, *Callinectes sapidus* showed them to be very similar in composition and food value. The crab meat protein was found to have approximately the same biological value as beef protein.

Ascorbic Acid (Vitamin C) Content of Raw, Cooked, and Canned Rhubarb. (C. R. Fellers, J. A. Clague, and Walter Stepat.) Rhubarb is a good source of vitamin C. The protective level for guinea pigs is 3 to 4.5 grams daily. Cooking the rhubarb into sauce causes a loss of 30 to 40 percent of the anti-scorbutic factor. Rhubarb canned in water does not protect guinea pigs from scurvy when fed at a daily level of 7 grams (5.3 grams of rhubarb). Titration studies with 2, 6 dichlorophenolindophenol show that the titration and the animal assay methods yield comparable results. This paper is now in press. (*Amer. Soc. Hort. Sci. Proc.*, Vol. 33.)

Home Canning Research. (C. R. Fellers, A. S. Levine and W. A. Maclinn.) Internal pressures in glass jars during thermal treatment in both water bath and pressure cooker were determined by means of specially constructed equipment. Similarly, two methods of accurately measuring vacuum in sealed glass jars have been devised, and the manuscript has been accepted for publication. (*Food Research* 1: 41–44.)

Two years of laboratory work and cooperative home canning in which all-glass jars of food were processed fully sealed, i.e., with the wire bails clamped down, have shown that this new canning procedure is dependable, safe and superior to the method in common use. The internal pressure within the jars during processing is never high enough to constitute a hazard. In this work 65 cooperators canned 15,355 jars of 41 different food products. This method decreases markedly the loss of liquid from jars during processing, improves their appearance, saves time, makes unnecessary the handling of the jars after processing, and has no effect on either breakage or spoilage. It seems likely that these results will greatly influence home-canning methods everywhere.

Use of Corn Sugar in Manufactured Fruit and Vegetable Products. (C. R. Fellers and Joseph Miller.) Purified crystalline corn sugar (dextrose) may be partially substituted for sucrose in many jams, preserves, jellies, canned and frozen fruits, and pickles. Usually more than 25 percent cannot be used because of crystal formation, insufficient sweetness, or a changed flavor. It cannot be used in canning sweet corn or peas because of marked darkening, due to the high pH value of these products. Dextrose added to cucumbers, peppers, or green tomatoes accelerates fermentation and increases acid production — both of which are desirable. Dextrose, used to the extent of 50 percent of the total sugar in sweet pickle products, improves both the appearance and texture of the pickles.

Frozen Food Investigations. (C. R. Fellers and Walter Stepat.) Fresh raw peas, shipped in iced hampers, lost 30 to 50 percent of their ascorbic acid (vitamin C) content after 24 to 48 hours. Frozen, blanched peas lost 35 to 65 percent of their ascorbic acid content after cooking. Under the same conditions, canned peas lost from 75 to 90 percent. Guinea pig bio-assays showed the average protective levels of peas to be approximately as follows: Raw peas as received in the pods at Amherst, 2.9 grams; fresh peas (cooked), 3.6 grams; frozen peas (cooked), 4.6 grams; and canned peas (heated), 8.8 grams. Similar studi esare being conducted on the effect of storage, freezing, and canning on the ascorbic acid content of spinach and lima beans.

Utilization of Cull Onions. (C. R. Fellers and J. A. Clague.) The only work on this project was in connection with the fermenting of small onions for use in relishes and mixed pickles. A salt concentration approximating 15 percent gave best results.

Nutritional Studies on Blueberries. (Oreana Merriam, C. R. Fellers and P. D. Isham.) Continued studies show little difference in vitamin C content among the important cultivated varieties. All are fair sources of vitamin C, with a daily protective level for guinea pigs of 8 to 12 grams. If blueberries are kept solidly frozen, no significant loss in vitamin C occurs. If defrosted and refrozen, serious losses occur. Canned blueberries are variable in their vitamin C content and range from fairly good to poor sources of this vitamin. The data are being prepared for publication.

Vitamin D Investigations. (C. R. Fellers, P. D. Isham, W. B. Esselen and R. E. Buck.) A summary of the work on the vitamin D potency of milks produced in Massachusetts has been published (*Amer. Jour. Pub. Health* 25: 1340–1345). Only 2.6 percent of the samples of vitamin D milk examined were seriously deficient in this vitamin. Vitamin D assays are being conducted on certain fish meals used as poultry foods, and also on the body and liver oils of the Atlantic whiting. Cooperative work with the A.O.A.C. Committee on Vitamin Standardization has also been carried on with a view to setting up standard methods for vitamin bio-assay.

DEPARTMENT OF OLERICULTURE

Grant B. Snyder in Charge

Packet Seed Studies. (G. B. Snyder and A. P. Tuttle.) A large majority of home gardeners buy their vegetable seeds from the neighborhood store in either packet or bulk lots. It has been found that seeds purchased in this manner frequently have a variable germination and are not true to the name under which they are sold. In order to check these factors, state inspectors purchased some 207 lots from various stores in the State. These included eleven of the more common vegetables.

Field notes on germination indicated fair vitality of most lots. A few samples of lettuce and beans failed to germinate and others germinated from 30 to 60 percent. The various lots were surprisingly true to name. Off types were noted in only a few cases, and even where observed the percentage was very small.

Systematic Studies of Turnips and Rutabagas. (G. B. Snyder.) Detailed plant and root records were taken of 26 lots (14 varieties) of rutabagas and 35 lots (16 varieties) of turnips. This is a cooperative project with the Federal Division of Fruit and Vegetable Crops and Diseases, and the data obtained will be used in the compilation of a Federal type book.

Systematic Studies of Vegetables. (A. P. Tuttle and G. B. Snyder.) During the past few years a large number of improved and new varieties of vegetables have been offered to the vegetable grower. In order to evaluate these newer sorts, they were planted in the trial plots along with the more important standard varieties. Performance, quality, and value for commercial and home-garden purposes were recorded for both groups. The following is a partial list of the varieties and strains of each kind of vegetable studied: Lima beans, 67; New York lettuce, 37; tomatoes, 90; beets, 21; celery, 43; carrots, 37; peppers, 36; hybrid sweet corn, 90.

Many of these newer sorts did not prove as satisfactory as the present standard varieties and are not adapted to Massachusetts conditions.

Seed Treatment of Lima Beans. (A. P. Tuttle.) Preliminary studies on the influence of red oxide of copper on the germination of lima beans indicated that under normal field conditions this fungicide did not inhibit seed germination. In most cases the treated lots produced a better stand of more vigorous plants than the untreated lots.

Asparagus Investigations. (Robert E. Young, Waltham.)

Fertilizer Experiment. This experiment has been concluded with this year's records due to the labor expense involved and the withdrawal of cooperative funds. It has also been found that the experiment was not producing reliable results which could be used to formulate conclusions of material aid to our asparagus growers. Certain observations and conclusions may be drawn from the three series of plots that were located at Concord, Waltham, and Eastham, Massachusetts.

1. During the first two years the asparagus located on the coarse sandy gravel soil at North Eastham on Cape Cod gave approximately double the yield obtained at Waltham on a heavier soil. In later years the advantage was slightly less. A comparison of the Concord plots located on a fine sandy soil and the Waltham plots indicates that the Waltham soil produced a slightly better yield all during the experiment. Part of this difference is probably due to factors other than the soil.

2. The results of the experiment lead to the conclusion that organic matter in the form of either manure or seaweed is of utmost value in the early development of the asparagus plants and in the production of high yields of asparagus. The supply of organic matter in the soil of asparagus plantings should be maintained at a fairly high level by the application of manure or some other form of organic matter if above average production is to be obtained.

3. The yield of asparagus was greatly increased by the application of an ample supply of potash. Under the conditions of the experiment, this amount was 700 pounds per acre. The most economical application appeared to be nearer 500 pounds per acre. Muriate of potash produced much better yields than did either sulfate or nitrate of potash.

4. The use of calcium cyanamid proved to be an excellent method of controlling weeds either during or after the cutting season, and at the same time supplied all the nitrogen necessary. The lime residue would also be of value in maintaining the proper soil reaction for asparagus.

Varietal Improvement. An analysis of the individual yield records obtained from 278 selected asparagus plants shows that the plants that produced a good yield in 1933 and 1934 were among the best producers this past year. The average production for all plants was 11.5 spears weighing 15.6 ounces. The female plants produced an average of 8.9 spears weighing 14.0 ounces as compared with the male plants that produced 13.8 stalks weighing 16.9 ounces. The average spear production for the 10 highest plants was 194 percent above the average spear production of all plants. The weight of spears for the highest 10 was 161 percent above the average for all plants. Records were made of the number of stalks sent up by the plants during the summer, and a positive correlation was found between the production of a large number of stalks in the summer and high yield during the cutting period.

There seems to be considerable difference in the denseness of the growth of these plants. All plants were classified as having dense or sparse growth. When the yields of these two groups were compared it was found that the plants having dense foliage were the largest producers.

The five highest yielding female plants were paired with the high five males for the production of seed. By the use of cages and both hand and fly pollination, sufficient seed was obtained for future trial to determine the yielding power of the various lines.

Depth of Planting and Height of Cutting. The results from the depth-of-planting phase of this experiment have changed only slightly from the results obtained for the past two years. Deep planting (8″) has reduced the stand and thus the yield, while the shallow planted roots (2 to 4″) have apparently not been injured by either cultivation or freezing and thawing.

Due to the late start of the asparagus season and to the fact that the cutting was not quite so prolonged as usual, the yield was below that of last year. In the height-of-cutting experiments, the plots where the spears were cut with 4 inches of green yielded about the same as last season. Where the spears were cut with 8 and 12 inches of green, the yields were considerably below the yields of last season. While the yield from the plot where spears are cut with only 4 inches of green was not reduced by the shortened season, it was still much below that produced where the spears are allowed to grow until 8 or 12 inches of the stalk is green. Cutting asparagus with only 4 inches of green has not increased the yield, as many growers expected.

Seed Improvement. (Robert E. Young, Waltham.)

Waltham Scarlet Shell Bean. Approximately 60 samples of an improved French Horticultural bean were distributed to leading bean growers under the name of Waltham Scarlet Shell bean. Of the growers who returned the questionnaire, 89 percent stated that it was a better bean than they were able to secure from established sources.

The distribution of the samples was such that the bean was considered satisfactory for most of the important vegetable growing sections of the State. Sufficient stock seed has been produced to insure an ample supply of seed in the near future. Most of the growers found that the bean had a bright scarlet color with long straight pods, and produced high yields with most of the pods ripening at the same time.

Waltham Beauty Pepper. During the past season extensive trials of peppers were made for the purpose of determining the value of the Waltham Beauty pepper. This new pepper was the highest producer in comparison with eleven of the most important pepper varieties available, and was second in earliness and thickness of flesh. During the spring 125 growers asked for samples of seed for trial. Of these growers 60 percent considered the pepper better than the variety they are now growing; 28 percent indicated that the Waltham Beauty was as good as their present variety; and 12 percent reported it to be inferior. It has been found that under conditions where the California Wonder type peppers will set and produce a satisfactory crop the Waltham Beauty does not yield well. On the Field Station grounds the Waltham Beauty produced over four times as much fruit as the California Wonder.

Breeding and selection for better uniformity were continued with the result that a selection bearing the fruit down-curved in contrast to the upright fruit of the Waltham Beauty has been improved so that it gives almost as high a yield as the latter.

The Waltham Beauty pepper was exhibited at the Massachusetts Horticultural Society fall vegetable show and received the Society's highest award, a First-class Certificate.

Tomatoes. An improved selection of the Field Station Comet, now known as Waltham Forcing Tomato, has been distributed among growers. In the greenhouse at the Field Station the tomato proved to be as high a producer as the parent from which it was selected, and had only 10.8 percent No. 2 fruit as compared to 18.2 percent produced by the parent. The new selection is larger and there is less of the green color on the stem end of the tomato than originally. Approximately 75 percent of the growers in the Boston area are using the Waltham Forcing tomato or a strain that at one time was derived from it. A cross between the Waltham Forcing and the Lloyd is proving satisfactory as an outside trellis tomato for some growers. Selection is being continued to improve the core of the fruit.

Bel-May Lettuce. Three selfed lines of selected Bel-May lettuce were distributed to leading growers of greenhouse lettuce this past season. Only a part of the growers have completed the trials, but those reporting state that the strains are very even and practically free from any deformed plants such as appeared in the regular Bel-May strain. Of the three strains distributed, No. 1 has a very small frame with a medium size head; No. 2 has a medium size head and frame; and No. 3 has a large rather loose head and medium large frame. The No. 3 is more like the May King, one of the parents of the Bel-May.

Wyman Crosby Beet. Selfing and selection were continued with the Wyman Crosby beet in an effort to improve the internal color. It has been impossible so far to secure a beet that has deep internal color along with earliness, uniformity, and good external appearance.

Blue Hubbard Squash. Six selfed lines of Blue Hubbard squash were compared with two strains grown by leading squash growers. Under our conditions the selfed lines were superior in yield and had a better color and a harder shell, but did not have as desirable shape, nor were they as warted as many growers consider ideal for market squash. Crosses were made between selfed lines and also between selfed lines and the commercial strains in an attempt to improve the shape and regain some of the vigor of vine growth lost during the selfing. The selfed lines produced a large number of small to medium sized, very uniform squash as compared to the very mixed lot found in most commercial strains.

Cucurbita Pepo. A genetical study was undertaken during the year which involves certain crosses in *Cucurbita pepo* between a line having a hard testa such as is usually found in the common sorts and one having a soft green testa. Crosses were made last year in the greenhouse, but when the seed was grown outside it was found that the soft-seeded strain was not homozygous for the soft-seeded character. Many plants were selfed last summer to purify the strain.

Hutchinson Carrot. The stock seed of Field Station strain of Hutchinson carrot is being maintained, and efforts have been made to improve the core of the carrot without sacrificing any of its desirable characters. Crosses between the Hutchinson and the Tendersweet that looked so promising last season were lost from rot during the spring. Approximately 500 pounds of carrot seed produced from Field Station stock seed was merchandized by a farmers' association during the past year.

Celery Storage. (Robert E. Young, Waltham.) In connection with the celery storage work, experiments were conducted to determine to what extent the sugars and stored materials in the outside petioles of celery moved to the heart for the elongation and enlargement of the small center petioles that go to make up the marketable portion of Pascal celery. It was found that there was quite extensive loss of weight by the outside stalks and a gain by those in the center. This loss by the outside stalks was 30 percent, of which 11.5 percent was not accounted for by gains of the center stalks. There was some rotting of the celery leaves, and it is difficult to estimate what portion of the 11.5 percent loss was due to rot and what was due to respiration. The celery was in storage at 32° to 35° F. for over four months. Refractive indices obtained from the expressed juice of the celery petioles indicated that there was about 4 percent soluble solids in the outside petioles. The percentage gradually increased in the stalk until it reached about 6.5 percent in the center. These percentages did not change much as the celery remained in storage.

The results of the celery storage experiment indicate that much of the loss experienced by the growers has been due to packing the celery too tight, thus preventing proper circulation of air around the lower portion of the petioles. A temperature of 32° to 36° F. has proved to be the best for the storage of Pascal celery. The humidity in this compartment ranged from 75 to 95 percent and seemed to be satisfactory. By the use of refrigeration, celery was kept in a marketable condition about a month after commercial celery had disappeared.

DEPARTMENT OF POMOLOGY

F. C. Sears in Charge

The winter of 1934-35 was, like the previous one, of unusual severity. The minimum temperature was nearly as low but there was much less damage to fruit plants. The peach crop in the college orchards was a complete failure though there was a scattering crop in the State. Baldwin trees failed to produce a normal crop, probably due to the weakening effect of the winter of 1933-34. The apple crop was a little larger than that of the previous year.

The Interrelation of Stock and Scion in Apples. (J. K. Shaw.) The potash deficiency problem in the stock and scion orchard continued. Muriate of potash was again applied to the entire orchard except four rows. Tests for potash in the leaf petiole by Thornton's method indicated a higher content in the potash-fertilized trees, but there was slight, if any, improvement in the appearance of the trees. This work will be continued to see if the trees improve next year.

Work with the Malling types of clonal stocks was continued. About 5,000 grafts of scions of these stocks on seedling roots were made in midwinter instead of April as in the previous year. Results however were not encouraging. The scion wood was exposed to ammonia fumes from the cold-storage compressor which may have had an injurious effect. This question will be investigated.

The nurse root grafts in 1934 that failed to root from the scion and were reset, rooted well, especially where new growth was covered with soil. If nurse root grafts are cut at the surface of the ground and the row hilled up as soon as growth is made, rooting will be greatly favored.

The orchard in South Amherst set in the fall of 1934 gave a good stand of trees but made small growth. This was probably due to the drought in late summer which was severe on this gravelly soil.

The entire crop of shoots from the stool bed of Malling stocks was cut in the fall of 1934 leaving only the root systems. These sprouted slowly in the spring but eventually nearly all made new shoots. The shoots that had rooted were cut in the fall of 1935 but one or more shoots were left on each plant. Evidently severe cutting is harmful to a young stool bed.

Tree Characters of Fruit Varieties. (J. K. Shaw and A. P. French.) To study and place on record characters by which all our fruit varieties can be identified in the nursery will require a long time. A publication is in preparation which will include nearly one hundred varieties of apples most commonly grown in our nurseries, containing illustrations of the leaf, one-year and two-year trees, and flowers, together with a technical description, chief distinguishing characters, and differences from similar varieties.

Another effort to build up a cherry nursery containing all varieties commonly grown in nurseries was made this summer. The buds were waxed with melted paraffine and there seems to be a better stand of buds than was obtained previously.

The variety certification work of the Massachusetts Fruit Growers' Association was continued as for the past fifteen years. Inspection for trueness-to-name but without certification was increased by the examination of two large nurseries in Maryland and Delaware, making ten in all, and two requests were refused because they were made too late. It is expected that there will be further increase in this work next year. When varieties are set right in the nursery row, few misnamed trees will be sold to growers. There was this year one case of fifty misnamed trees coming from an inspected nursery. This may be a case of erroneous labeling after digging, or it may be that the trees were grown in an uninspected nursery and not in the inspected nursery. All this work is done in vacation time and without expense to the Station.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) During the winter of 1934–35 all fruit buds of the peach were again killed by low temperatures so that no crossing work could be done in 1935. In the spring of 1935, 1082 selfed and crossed seedlings were transferred from the nursery to orchard blocks; also 44 budded trees from 12 selected seedlings were set in an orchard block for further trial.

Effect of Pruning Bearing Trees. (J. K. Shaw and O. C. Roberts.) The results of this project were summed up in Bulletin 320 published during the past year. While some of the work is being continued the project may be considered completed.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) This project has been carried on as for the past five years. The crop was small on both McIntosh and Baldwin. Probably the latter variety still suffers from the cold winter of 1933–34 which hurt the trees though none were seriously killed back. The two plots having a complete fertilizer continued to do well.

Tests of Different Amounts of Nitrate of Soda. (J. K. Shaw.) The Baldwins in this orchard were severely injured by the cold of the winter of 1933–34 and three trees have been removed on this account. The practice of fertilizing only in the off year is being continued and there was practically no crop the past season.

Comparison of Cultivation and Heavy Mulching for Apples. (J. K. Shaw.) This project has been carried on as in the past six years. No fertilizer has been used on the mulched plots since the project was begun in 1922. The cultivated plots have received nitrate of soda at the rate of 300 pounds per acre since 1930. The Wealthy trees have always been strongly biennial in bearing and the McIntosh has shown some tendency in this direction for the last six years. All plots are keeping up production quite well. A bulletin based on this project is in preparation.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw.) This project has continued as in the past. The trees on the limed plots that received potash, alone or in combination, continued to grow better than those on the unlimed plots; while the reverse is true on the plots that received nitrogen and phosphorus, alone or in combination. On three of the four plots that have received no fertilizer for more than forty-five years, there is little difference between the limed and unlimed plants; on the fourth plot the unlimed trees are better.

Further tests for potash in the leaf petiole, using the method of Thornton, confirm results reported last year. On the nitrogen-phosphorus plot, potash in the petioles was very high on the unlimed part and very low on the limed part. The same was true of the phosphorus plot. Otherwise the potash content followed the fertilizer applications rather closely but with some variation in individual trees.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw.) This project was continued as in previous years beginning in 1927. The sod was broken up, as in 1934, with a heavy harrow and this practice seems beneficial to the trees. The answer to the question whether nitrogen alone is enough to meet the fertilizer requirements of this orchard is a negative one; the addition of potash to nitrogen has resulted in increased crops.

Study of Varieties of Fruits. (J. K. Shaw and O. C. Roberts.) Observations on new varieties continues to be an important part of the work. While there is not room for all of the many new varieties offered for the consideration of fruit growers, an effort is made to obtain all that promise to be valuable in Massachusetts.

Plum. Wright's Early Plum failed to crop for the first time since reaching bearing age. This is attributed to the severe cold of the past two winters. There was, however, little killing of the branches. It is hardier than Red June and Beauty, competing varieties of the same season.

Peach. For a second year the newer varieties of peaches failed to produce a crop. This is the first time in over twenty-five years that two successive peach crops have failed.

Strawberry. Dorsett and Fairfax are two new varieties of strawberries originated in the United States Department of Agriculture and regarded as possible replacements for Howard 17 (Premier). Both are excellent plant makers. Berries are large and of satisfactory quality. We are now inclined to prefer Dorsett on account of its superior quality and more attractive appearance. Both are worthy of extended trial.

Clermont is a new variety from the New York, (Geneva) Station and the most promising of any yet received, but like others from Geneva considerably affected by leaf spot.

Green Mountain is a new everbearing variety from the Aiken Nursery, Putney, Vermont. The fruit is medium to small, not attractive in appearance, and of only fair quality. The variety is subject to leaf spot.

Raspberry. Several plants of the Newburgh raspberry developed mosaic, from which this variety had previously been free. The affected plants have been left to observe the spread of the disease. However this variety continues to promise to be one of the best.

Another seedling raspberry received from Geneva under the number 5555, which has been named Taylor, fruited for the first time. The plants are very vigorous with large attractive berries of good quality. It appears very promising but further experience is needed before an evaluation can be made. We have a considerable number of new seedlings from Geneva under trial among which one under the number 5220 seems most promising.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter.) A summary of the results of this project to date will be published in the Annual Report of the American Society for Horticultural Science.

This project has now been redirected in order to study the effect of time of planting on fruit bud formation. Plots of 51 plants each were set on April 29, May 15, and June 1. Each planting was replicated five times. To eliminate complications arising from a varying stand of plants, each parent plant was allowed to form two runner plants only.

To study the effects on fruit bud formation of CO_2 in the soil, one-third of the plants in each plot were fertilized with two ounces of dextrose per plant on July 18, one-third were fertilized with one ounce dextrose and one-half ounce of nitrate of soda per plant, and one-third were left untreated. The materials were applied in solution in a shallow trench about each plant under the leaves.

If the differential treatments produce noticeable differences, this problem will be studied more intensively.

Bud Mutations. (J. K. Shaw and W. H. Thies.) A few of the probable mutations produced fruit but too scatteringly to give a basis for definite conclusions. Next year there should be enough fruit for this purpose. The "flat limbed" strain of Gravenstein continues to produce only normal wood.

Storage of Apples under Various Conditions. (O. C. Roberts cooperating with Agricultural Engineering Department.) Work on this project was continued on much the same lines as last year and the conclusions previously reached were confirmed. Evidence accumulates that, in order to develop and maintain the best quality in McIntosh, careful attention must be given to storage conditions.

Some attention was given to the problem of the best date for picking Cortland. Apples were picked and placed in storage on September 19 and 27 and October 5 and 11. Half of each sample was held continuously at 32° and half put in at 45° which was gradually lowered to 32° after the harvest season. These showed more scald than the first lot. Samples from both lots were brought into a warm room at different times and their condition and behavior observed. Scald was worst on those picked September 27 and no scald developed on those picked October 11. There was not much scald on those picked September 19, but the quality and appearance of the apples was inferior. Those picked October 5 showed little scald and were of good quality and appearance. No internal breakdown appeared in any of the samples.

This test indicates that Cortland apples should not be picked until two to three weeks after the McIntosh harvest. Further observations must be made before this is well established.

Tests of Various Spray Materials. (O. C. Roberts cooperating with Entomology and Botany Departments.) While limited resources prevent extensive tests of the many spray materials offered in the market, this department has continued during the past year to make orchard tests of those most promising. The results are discussed in the report of the Department of Entomology.

Removal of Arsenic and Lead Residues from Apples. (O. C. Roberts and J. K. Shaw cooperating with Departments of Entomology, Agricultural Engineering, and the Fertilizer Control Service.) The problem of possible excessive lead residues is one that confronts our growers. Thus far practically no fruit is washed in this State though several wipers are in use. Our work is directed chiefly toward methods of spraying to avoid the chance of excessive residues. With a suitable spraying program, it is possible to keep within the present lead tolerance established by the United States Department of Agriculture. Whether residues can be kept below the prospective lowered tolerance of lead is yet a problem. On account of the withdrawal of analytical service by the United States Food and Drug Administration this work will be done by the Station Fertilizer Control Service. Samples of apples sprayed under various programs await analysis.

Blueberry Culture. (J. S. Bailey.) In the spring of 1935 the blueberry plantation started in 1932 (Plot C) was enlarged by the addition of 346 plants of the varieties Pioneer, Concord, Cabot, Scammell, Jersey and Rancocas. This plot now covers three-fourths of an acre. Another plantation (Plot D) was set in the spring of 1935, covering two acres and containing 1948 bushes of the varieties Cabot, Pioneer, and Rubel. These plots are to be used for cultural experiments.

The experiment started in 1934 to test the effect of varying amounts of lime and of sulfur on blueberry plants in Wagner pots was continued. The plants used in 1934 were removed and a new set of two-year-old Rubel plants set in their places. The general trend of results was the same as in 1934 except that there was increasing evidence of sulfur toxicity. Most of the plants in the sulfur-treated pots died soon after planting. The plants in the pots which received 5 gms. of sulfur made a very poor growth in 1935 although they made the best growth in 1934.

The average total shoot growth per plant for 1935, the average total height of plants, and the pH for each treatment is given in the following table.

Treatment	*Average total growth in inches*	*Average height in inches*	pH
Check	35.3	11.7	4.60
Lime 10 gms	47.0	18.3	5.20
Lime 20	34.3	10.0	5.50
Lime 30	31.7	13.3	5.55
Lime 40 (2)	21.7	9.0	5.75
Lime 60 (2)	29.5	13.0	6.75
Lime 80	25.0	9.3	6.75
Peat	64.7	28.0	4.80
Peat + lime 10 gms	56.0	21.7	5.00
Peat + lime 20	46.0	16.0	5.30
Peat + lime 30	35.7	15.0	5.70
Peat + lime 40	26.7	9.7	5.95
Peat + lime 60	34.3	11.7	6.45
Peat + lime 80	22.0	9.3	6.65
Peat + sulfur 5 gm. (2)	36.0	10.5	4.35

Growth measurements are averages of three plants unless otherwise noted. With heavier sulfur treatments all plants died.

An experiment was started in the spring of 1935 to test the self-fertility or self-sterility of varieites of blueberries. Most of the plants were under a large tent of tobacco cloth but some were in individual cages. All blossoms were hand-pollinated several times during the blooming season. A number of flower clusters on each of several bushes of a variety were tagged, the blossoms counted and the percentage of set obtained from these tagged clusters.

The percentages of set obtained were as follows:

Concord	74.3	Katherine	11.0
FI-66	60.9	Wareham	10.4
Stanley	56.5	Pioneer	6.7
Scammell	52.2	Durfee	6.3
Rubel	49.0	Adams	2.6
Cabot	48.0	Sam	2.2
Jersey	38.2	Grover	1.1
Rancocas	37.1	Harding	0.8

Some of the berries which set on these bushes were small and had relatively few seeds.

In the summer of 1935 an experiment was started to try out the acidification of the soil under field conditions. On July 30 parts of two rows of plants in a blueberry nursery were treated with sulfur at the rate of 1,000 pounds per acre; parts of two other rows, with aluminum sulfate at the rate of 5,000 pounds per acre; and parts of two other rows, with anhydrous aluminum chloride at the rate of 2,000 pounds per acre. The pH of the soil in this nursery ran from 5.8 to 6.0 before treatment. On October 23 the pH of the various plots was as follows:

Treatment	*North plot*	*South plot*	*Average*
Sulfur	5.50	5.60	5.55
$Al_2(SO_4)_3$	5.60	5.50	5.55
$AlCl_3$	5.20	5.40	5.30
Check (untreated)			5.80

At present no differences can be observed in the growth of the plants.

Some blueberry plants in the nursery, some in Plot D, and some in the pot experiments exhibited a chlorotic condition of the leaves. Preliminary experiments indicate that this may be due to a deficiency of iron.

DEPARTMENT OF POULTRY HUSBANDRY

J. C. Graham in Charge

Broodiness in Poultry. (F. A. Hays.) Efforts are being concentrated on the development of a genetically non-broody line that will breed true. The basic mode of attack is the use of aged parents that have been progeny-tested over a long period of time. The problem of deferred broodiness is being more fully investigated. Further attention is also being given to quantitative inheritance of the broody instinct as well as to the relation of broodiness to mortality rate of pullets in the laying houses.

Breeding Poultry for Egg Production. (F. A. Hays and Ruby Sanborn.) A number of problems in breeding Rhode Island Reds for high egg production are being given special study. Through cross-breeding, more specific information has come to light on the inheritance of persistency or duration of the pullet laying year. These studies confirm the previous report that high persistency depends in inheritance upon one dominant autosomal gene. These new data indicate that the dividing point between birds genetically high or low in persistency lies at about 270 days after the first pullet egg. Similar studies on sexual maturity point to a cumulative effect of genes E and E^1 giving pullets that begin to lay at under 180 days of age, while either gene alone gives an age range from about 180 to 215 days. Individuals lacking either dominant gene do not begin to lay until about 216 days or older.

Selection for low mortality in the laying houses is being made. Available data indicate that the use of breeding males that are at least three years of age is an important factor here. Range mortality up to September first is very low. The total loss to that date on 3200 chicks hatched in 1935 was less than 5 percent.

Characters affecting egg production are being studied further, together with such physical characters as comb type, ear-lobe color, stubs, and body size throughout the laying year. Egg production and egg size are constantly improving along with external quality of eggs.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn.) Data have been prepared and published on "Crossing Production and Exhibition Rhode Island Reds," Bulletin 316. The following papers are now in press: "Studies on the Inheritance of Persistency," "Numbers and Uniformity in Experimental Lots," "The Inheritance of Sexual Maturity in Rhode Island Reds," and "The Time Interval Between Eggs in Rhode Island Reds."

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) The behavior of plumage color in two lines of exhibition Rhode Island Reds is being studied. One line is being selected for plumage color alone and the other line is being bred for known fecundity characters. Some very satisfactory egg records have been made by the second line.

Rate of Feathering in Rhode Island Reds. (F. A. Hays.) Weekly records on feather development in the different feather tracts from hatching up to nine weeks of age are available on about 1800 chicks. Records on back feathering at eight weeks of age are available on over 6000 chicks. These data indicate that both a sex-linked and one or more autosomal genes are concerned in rate of feathering of Rhode Island Reds.

Breeding for Low Mortality. (F. A. Hays.) High and low mortality lines are now in the second generation. The data are inadequate at present, but they suggest that hereditary factors are of considerable significance in relation to mortality rate in the laying house.

Breeding for High and Low Resistance to Fowl Paralysis. (F. A. Hays, C. S. Gibbs, W. C. Sanctuary, and J. H. Vondell.) The incidence of paralysis in the first generation was as follows: Line A, 23 percent; Line B, 26 percent; and Line C, 10 percent. In the second generation the incidence of paralysis fell to 11, 9 and 5 percent, respectively, in the three lines. A preliminary study of the data suggests that paralysis may occur in birds lacking one dominant gene for resistance, but that a dominant inhibitor may prevent its occurrence in such individuals.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint, and M. K. Clarke.)

1. *Pullorum Disease Eradication.* The 1934–35 testing season has revealed a marked increase in the volume of testing along with progress in reducing the amount of infection among the tested flocks. A total of 247 flocks (including three flocks other than chickens) was tested. The number of blood samples tested from the 244 chicken flocks was 301,887, of which only 0.39 percent were positive. This percentage is the lowest attained during the fifteen-year testing period. Progress in eradication is further noted in that the percentage of flock owners who tested all the birds on the premises has increased from 66.8 in 1933–34 to 74.5 in 1934–35. Among the 213 non-reacting flocks, 163 were 100 percent tested. The number of flocks which were tested for three or more consecutive years was 161, of which 149 were non-reacting. The average percentage of positive tests for this group was 0.18, the lowest attained during the testing history in the State. It is clearly evident that the practice of annual

testing of all the birds on the premises, supplemented with sound eradication and preventive measures, is effective in establishing and maintaining flocks free from the disease.

The establishment of two official pullorum tested grades, namely, "Massachusetts Pullorum Passed" and "Massachusetts Pullorum Clean," by the Massachusetts Department of Agriculture should aid poultrymen in the buying of new stock from flocks which are officially recognized as free from the disease. This makes it possible to replace infected flocks with clean stock, and new stock can be introduced into pullorum disease-free flocks without the introduction of infection.

2. *Pullorum Disease Investigations.*

(a) Whole Blood Agglutination Test. During the past year investigations concerning the whole blood agglutination test were resumed in order to gain a more thorough insight into the factors which influence its effectiveness and its reliability in eliminating pullorum infection from poultry flocks. Laboratory and field experiments revealed that the whole blood agglutination test was not as efficient as the standard tube agglutination method. The results have been reported in Bulletin 323.

(b) Pullorum Disease Transmission by Feces from Reacting Birds. Experiments revealed that under an environment approaching practical natural conditions feces from reacting birds do not appear to be an important vehicle in the transmission of pullorum disease. Non-infected birds maintained on litter containing feces from reacting birds failed to develop the disease. However, non-infected birds force-fed with feces from infected hens contracted the infection in a few instances.

(c) Viability studies of *S. pullorum*, which are still in progress, have shown that the organism has remained viable on a dry piece of cloth for a period of 1,169 days.

3. *Diagnostic Service.* Personal calls at the laboratory were recorded 205 times. The number of cases handled was 546. The classification of 1,987 specimens follows: — 1,736 chickens, 121 ruffed grouse, 84 turkeys, 11 quail, 10 rabbits, 7 swine, 5 pheasants, 3 foxes, 3 purple grackles, 2 bovine and 1 each of canine, cod liver oil, corn fodder, muskrat, and raccoon. The diseases encountered most frequently were reproductive-system disorders, parasitism, tumors, avian paralysis, pullorum disease, and nephritis. The diagnoses of diseases which are believed to be rare in Massachsuetts were paratyphoid 2, fowl cholera 3, fowl typhoid 3, avian tuberculosis 1, and fowl typhoid in turkeys 1. Fowl cholera was noted in two new flocks and fowl typhoid in one, while avian tuberculosis was found on the same premises where it was noted two years ago. The poults in which fowl typhoid was noted were introduced from outside of the State.

4. *Flock Morbidity and Mortality Studies.* Morbid and dead specimens were examined from the Poultry Plant and Experiment Station flocks. From the former, 212 birds were examined during a seven months period. Cannibalism was noted in 111 of these birds, reproductive-system disorders in 38, tumors in 16, avian paralysis in 16, and injuries in 12. From the Experiment Station flock of 773 pullets placed into the laying houses in the fall of 1934, 207 were examined during a 14 months period. The diseases most frequently encountered were reproductive-system disorders 53, nephritis 40, tumors 29, leukemia 26, avian paralysis 19, and visceral gout 16. Limited observations on 120 morbid, live birds yielded meager information as to the etiology of the disease conditions.

5. *"Epidemic Tremors" in Chickens.* A group of 83 chicks from eight flocks showing symptoms of "epidemic tremors" was placed under observation at the

laboratory. The chicks were two to five weeks of age when received, the first symptoms being noted between the ninth and twenty-first days. Morbidity in the affected flocks varied up to almost 50 percent and mortality possibly up to 20 percent. After a period of approximately eight months, 24 chickens of the original 83 survived. The losses in this group from "epidemic tremors" were supplemented by losses from intercurrent diseases and by specimens sacrificed for experimental purposes. Blindness, a previously unreported symptom of "epidemic tremors," has been observed, following an opacity and bluish discoloration of the lens of one or both eyes. Seven of the 24 living birds show this condition. Progeny of the 24 survivors are under observation. A few of the progeny have exhibited a very fine muscular tremor at about five weeks of age, which was not observed in normal birds. Typical tremor and ataxia encountered in natural outbreaks of the disease were not observed in the progeny. In five trials 62 chicks from 2 to 24 days of age were inoculated intracerebrally with brain emulsions from affected chicks, and gross manifestations of disease were not observed.

6. *Disease Studies in Wild Animals.* Our knowledge concerning the influence of disease on the conservation of wild life is very meager at the present time. During the past year specimens (normal and morbid) have been investigated from anatomical and pathological points of view. Disease entities which were bacterial, fungous, protozoan, or parasitic in character, have been encountered in the various specimens. Most of the specimens examined were ruffed grouse which were reared in captivity by the Poultry Department. The majority apparently died from inanition when less than a week old. Renal disorders were rare, and perosis, noted frequently the preceding year, was not observed. Among a group of eight growing birds, ulcerative enteritis appeared during the month of August. All birds succumbed to this disease within a week. Through effective managerial and sanitary methods, ulcerative enteritis was prevented in birds that were maintained on wire. However, one case of entero-hepatitis was encountered in this group.

7. *Farm and Station Bang Disease.* In assisting this project, the laboratory tested 1,565 blood samples by the standard tube agglutination method.

Laryngotracheitis. (C. S. Gibbs.) Three outbreaks of laryngotracheitis in brooder chicks have been studied in which the viruses were of low virulence and produced clinical symptoms resembling colds. The virulence was not enhanced after passing serially through 36 chicks. These viruses neutralized two known laboratory strains of laryngotracheitis, and chicks immune to the field virus were immune to the laboratory virus and vice versa.

Colds. (C. S. Gibbs.) Two types of colds have been studied, one in which the symptoms and lesions are confined to the nostrils, infraorbital sinuses and turbinates, and the other in which the trachea and bronchi are involved. Both types are apparently due to the same virus, because they are readily transmitted to the nostrils, infraorbital sinuses and turbinates or to the trachea, depending upon the method and site of inoculation. Moreover, chickens made immune to one type of cold are immune to the other also. Chickens immune to these colds were not immune to laryngotracheitis, and chickens immune to laryngotracheitis were not immune to these colds.

Studies thus far seem to indicate that colds in chickens or laying hens are not serious unless they are complicated by secondary microorganisms. The most common complications appear to be *Staphylococcus albus*, *Streptococcus bronchitis*, and *Hemophilus gallinarum*. These microorganisms produce pus which tends to consolidate either in the infraorbital sinuses and turbinates, or in the trachea and bronchial tubes. Chickens and laying hens affected with colds complicated by any one of these secondary microorganisms are usually out of condition for a period ranging from two weeks to two months.

Experiments have been conducted in which chickens hatched and reared under strict laboratory conditions were inoculated with cold exudates containing microorganisms isolated from field cases, and the average period of sickness was 40 days. The symptoms were severe in these chickens and some of them died. Similar groups of chickens inoculated with bacteria-free ultrafiltrates of the cold exudate produced mild symptoms of colds. The average period of sickness was only three days, and none of the chickens died.

Inclusion Bodies in Laryngotracheitis and Colds. (C. S. Gibbs.) The inclusion bodies in laryngotracheitis are intranuclear, while those in the colds studied up to the present are extranuclear. Considerable variation appears in the shape and form of these bodies at different stages of the disease, indicating that they may undergo some kind of a cycle or growth. Furthermore, variation in the particulate size of these bodies, as measured by a graded series of acetic-cellodion membranes, indicates that the size of the inclusion bodies is not always the same. The laryngotracheitis virus particles average less than 0.082 micron in diameter, and the cold inclusion bodies average less than 0.135 micron in diameter, although experiments have been conducted in which the particles appeared to be the same size in both cases. Some of this variation may be due to the fact that laryngotracheitis is more virulent than colds, and the respective locations of the inclusion bodies in the epithelial cells of the mucous membrane tend to make the cold virus more readily filterable.

Differentiation of the Pathological Cell in Neurolymphomatosis from Lymphocytes of the Blood of Chickens. (C. S. Gibbs and C. G. Johnson.) Unna's eosin and methylene blue stain is modified and successfully used to differentiate pathological cells in neurolymphomatosis from lymphocytes in smears by substituting Lugol's solution for iodized alcohol and reducing the length of time necessary for differentiation in the alcohols. In this way the smears are not washed from the slides and comparative studies of the cells are made under identical conditions — an achievement that has not been accomplished before. With this technique it has been found not only that many of the pathological cells in neurolymphomatosis undergo mitosis, but that the nuclei are more vesicular than the nuclei of the lymphocytes of the blood.

By means of this staining technique cells indistinguishable from those occurring in neurolymphomatosis are found in the follicular fluid of hens, in the semen of roosters, and in the perivascular infiltration in the peripheral nerves of baby chicks produced by affected hens and roosters. While these findings are suggestive that neurolymphomatosis may be transmitted through the egg, the final results are not entirely conclusive because many of these cells are apparently destroyed in the developing embryo by some factor or factors unknown at the present time.

The Differentiation of Neurolymphomatosis from Lympholeukosis. (C. S. Gibbs and C. G. Johnson.) Histological studies indicate that the fowl does not possess lymph glands and lymph nodes anatomically and physiologically comparable to those of higher animals, but does possess relatively large amounts of lymphoid tissue in the bone marrow, liver, spleen and in certain locations along the digestive tract. This tissue is closely associated with the vascular system by means of capillaries. In lympholeukosis this lymph tissue appears to be in a state of hyperplasia, and the number of lymphobasts in the tissue and the capillaries is materially increased over that in the healthy fowl. In neurolymphomatosis the lymph tissue appears the same as in normal birds In this respect, as well as in the locations of the pathological cells, lympholeukosis is distinguished from neurolymphomatosis thus supporting the view that the two diseases are of different origin.

A Study of "Pearly Eye" in Neurolymphomatosis. (C. S. Gibbs and C. G. Johnson.) Gross and microscopic examinations of "pearly eyes" in neurolymphomatosis indicates that neurolymphomas form in the ciliary nerves, and interfere with the stimuli going to the ciliary muscle and iris. Since neurolymphomatosis is a progressive disease, not all of the ciliary nerves are affected at once. This accounts for the distorted appearance of the pupil in birds affected with this form of the disease, until all of the nerves are affected and the iris contracts, resulting in complete closure of the pupil and total blindness.

WALTHAM FIELD STATION

(Waltham, Massachusetts)

Ray M. Koon, In Charge

For reports on approved projects conducted at this station, in addition to those listed under this caption, see reports of the Departments of Botany, Entomology, Floriculture, and Olericulture.

Following an organized request by the Massachusetts Nurserymen's Association for research in their interest, the trustees were successful in securing a special appropriation for instituting and maintaining a service in Nurseryculture at Waltham. Professor George Graves was added to the staff to conduct this department, and the office and laboratory building was enlarged to accommodate the new activity.

Consultation and Information Service. Not only have the calls for service on the part of commercial horticultural interests increased, but amateur gardening and the expansion of civic improvement have brought an increasing number of persons to the station during the year for personal conferences. A count of these, and in addition those who came for other purposes, runs well over 7,000. More than 3,500 telephone calls were checked, the majority from persons seeking definite information. In 1934, Paul W. Dempsey was appointed to relieve the research men of some of this growing activity, and the arrangement has proved satisfactory in a large measure. At the request of various organizations he has given 105 talks on the work of the Field Station and on general horticultural subjects during the year.

Soil Testing Service. (Robert E. Young, Harold E. White, Paul W. Dempsey.) Soil samples were tested for acidity with the Potentiometer. Determinations were made for nitrate nitrogen, phosphorus, and occasionally potash.

Summary of Sources

Commercial Growers — fields	259
greenhouses	610
Amateurs — lawns, flower gardens and vegetable gardens	588
Miscellaneous — golf courses, lawn contractors, landscape gardeners, Metropolitan District Commission	84
Total	1,541

Summary of Acidity Tests

	Samples from Greenhouses		
pH	Vegetables	Flowers	All Others
7.0–7.5	44	10	44
6.5–6.9	95	70	101
6.0–6.4	90	93	224
5.5–5.9	36	82	313
5.0–5.4	6	56	155
4.5–4.9	0	23	81
4.0–4.4	0	4	18

The Plant House. (Paul W. Dempsey.) Because of the feeling that economic conditions are improving, there is a renewed interest in the plant house, shown by the increase in the demand for plans. Both plant houses at the Field Station are used for growing crops the year around, proving their value for other purposes besides the production of early plants.

Electricity as a Source of Heat in the Hotbed and Propagating Bench. (Paul W. Dempsey.) Results obtained this year in both the experimental and some commercial installations emphasize the observations of the past four years that operating costs are a limiting factor in the use of electricity for this purpose. A few amateur gardeners have installed the equipment and find operation costs on a small scale reasonable in comparison with previous costs of other methods.

Vegetable Variety Trials. (Paul W. Dempsey.) Because of absence of the Stewart's Disease again this year, it was impossible to obtain resistance records on the many new crossed varieties included in the sweet corn trials. A few new varieties were tried out but none showed any outstanding characteristics. Most of the strains were of the new crossed varieties, some of them maturing much earlier than any previously tried.

Most of the new and old standard varieties of tomatoes were included in the trials. Plants of each variety were set both flat culture and trellis style. New early varieties are introduced each year in an attempt to supplant the Earliana, which is of poor quality, but not one of these shows any superiority.

Field Day. The Seventeenth Annual Field Day was held on August 7 with an attendance of 1,290 market gardeners, florists, fruit growers, nurserymen, and others. The plan of conducting groups about the grounds at scheduled intervals was tried for the first time and proved a successful means of acquainting the visitors with the details of what is actually in progress.

Ornamental Display and Test Gardens. (Harold E. White.) Public interest in the perennial gardens still increases as is evidenced by the number of visitors, which doubled this year over the year 1934. The attendant who is on duty in the evenings from 5 to 8 o'clock and on Sundays checked an attendance of 3,872 persons from June 1 to October 30. The gardens have been redesigned and many improved varieties have supplanted others less worthy.

Horticulture School. (Harold E. White.) The fifth school for home gardeners was conducted on April 9 and 10. The program was considerably more diversified than had ever before been attempted and proved so successful that in the future a very comprehensive group of subjects will be the rule.

PUBLICATIONS

Bulletins

315 Annual Report for the Fiscal Year Ending November 30, 1934. 84 pp. March 1934.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

316 Crossing Production and Exhibition Rhode Island Reds. F. A. Hays. 16 pp. January 1935.

It is a widely recognized fact that production-bred Rhode Island Reds differ significantly from exhibition-bred birds of the same variety in a number of specific characters. The purpose of this five-year study was to determine whether, through crossing, the characters necessary for high egg production might be retained without the sacrifice of plumage color. It was found that by crossing light-colored production-bred Rhode Island Reds with exhibition-bred birds, followed by careful matings, a flock could be built up with rather uniform medium-red plumage color and high egg production.

317 Blueberry Culture in Massachusetts. John S. Bailey and Henry J. Franklin. 20 pp. illus. February 1935.

Wild blueberries are native to New England, but it is only within recent years that any attempt has been made to develop improved varieties. Breeding work conducted by the United States Department of Agriculture has resulted in the production of several named varieties with fruit larger and more handsome than the wild. Although relatively few acres of these named varieties have been planted in Massachusetts, there is a growing interest in their culture which has led to an increased demand for information about them. This bulletin is meant to serve as a guide to those interested in growing blueberries—whether the newer cultivated varieties or the native wild berries.

318 Onions in the Connecticut Valley. A. B. Beaumont, M. E. Snell, W. L. Doran, and A. I. Bourne. 32 pp. illus. May 1935.

Massachusetts has been one of the leading states in the production of onions for a hundred years or more and their commercial culture in the Connecticut Valley dates back to 1885. Prior to 1920 most of the onions of the Valley were grown from seed. Since that time the acreage of onions grown from sets has increased rapidly, largely at the expense of the acreage grown from seed. Among the practical problems facing the grower in the Connecticut Valley when these experiments were started were the use of lime, the choice and method of applying fertilizers, the value of cover crops, spacing, growing of sets, and improvement of onions by breeding and selection, as well as diseases and insect pests. The results of experiments concerned with these problems are reported in this bulletin.

319 A Study of the Variation of Salmonella Pullorum. H. Van Roekel. 60 pp. illus. March 1935.

Bacterial variation has played an important role in bacteriology and related fields of science. From a practical point of view, and particularly in the diagnosis, control, and eradication of human and animal diseases, it has presented problems of great importance. Since bacterial variation has received little attention in the study of pullorum disease, the investigation reported in this bulletin was undertaken to add to our knowledge on this subject.

320 Pruning Bearing Apple Trees. J. K. Shaw. 16 pp. illus. June 1935.

Few careful experiments have been made to determine whether current beliefs and practices in regard to pruning bearing apple trees are sound. For the last eight years this Station has carried on experiments directed toward this end. With younger bearing trees in full vigor of growth, pruning has less effect in improving size and quality of fruit than has been commonly believed. Other factors were found to be of much greater importance than pruning. Cutting out weak and declining wood will not decrease the size of the crop, but will eliminate much of the low-grade fruit that scarcely pays for the handling. The sooner such wood is removed, the better. Well-cared-for bearing trees should be gone over annually if possible, but at least every two or three years, and this type of wood removed. Water sprouts should also be removed unless needed to maintain or renew the top. However, if one is forced to economize on labor, it is less injurious to neglect pruning than to cut down on spraying or neglect proper cultural treatment.

321 Tankage as a Source of Protein for Dairy Cows. J. G. Archibald. 8 pp. July 1935.

Tankage, especially the better grades, has a common use as poultry and hog feed, but interest in its use as a source of protein for dairy cattle is of very recent development. Investigations of the value of tankage for milk production showed that high-grade tankage can be safely added to the list of protein feeds for dairy cows, provided the usual precautions for feeding protein concentrates are observed.

322 The Effect of Fertilizers on the Longevity of Mowings. A. B. Beaumont, R. W. Donaldson, and M. E. Snell. 8 pp. July 1935.

There are several good reasons why it is desirable to prolong the life of mowings in Massachusetts. In the first place, much of the land used for hay in this State is so stony as to make plowing difficult. Secondly, since under ordinary conditions it is more economical for the Massachusetts dairyman to purchase his grain than to produce it, a relatively large acreage must be kept in forage crops. Finally, farm labor is relatively more expensive in Massachusetts than in less industrialized regions, and any method of farming which reduces labor expenditures is desirable. The two experiments reported in this bulletin showed that quality and yield of hay can be improved and the life of the mowing prolonged by the use of fertilizers. However, the quality of mixed grass mowings will deteriorate to such an extent in six to eight years that reseeding is desirable, even when fertilizers are used at fairly high rates.

323 The Whole Blood Agglutination Test for Pullorum Disease. H. Van Roekel and M. K. Clarke. 24 pp. illus. July 1935.

The whole blood test was introduced several years ago in response to a demand for a method of testing less expensive than the standard tube test. It has not, however, proved entirely satisfactory, and this study was undertaken in the interests of increasing its efficiency and reliability. Factors such as proper and constant incubation temperature, incubation time, adequate light for reading the agglutination reaction, and an effective and constant whole blood-antigen dilution influence the sensitivity and efficiency of the whole blood agglutination test. The great variation observed in the whole blood-antigen dilution exerted a perceptible influence on the degree of agglutination and played an important role in detecting low-titre birds. Delayed weak reactions were encountered in blood from birds that harbored the infection. The standard tube test detected infected birds which failed to react with the whole blood method. The adoption of the whole blood test as the sole diagnostic means for establishing and identifying pullorum disease-free flocks seems inexpedient at the present time.

324 Potash in Massachusetts Soils: Its Availability for Crops. F. W. Morse. 16 pp. August 1935.

This bulletin brings together results from soil surveys, soil analyses, and general investigational work in Massachusetts with the aim of promoting the more efficient use of potassium as a plant-food element. The soils of this State are derived from glacial drift, which consists principally of material from potash-bearing rocks. Fertilizer experiments have shown that the lighter soils required potash, while heavy clay soils did not. Characteristic soils were separated into two groups of soil particles, sands and silt-clay. Chemical analyses showed clay to contain slightly more potash than sand. Clay holds more soil water than is held by sand, and its fine particles are more readily dissolved than the sand grains. Therefore, clay soils of this State will supply more available potash than sandy soils of similar origin. Efficient use of potash fertilizer should include the available soil potash as part of the supply for the crop.

325 Poultry Flock Improvement. J. C. Graham. 8 pp. illus. October 1935.

The purpose of this project was to determine whether it is possible to maintain or improve body weight, feather color, egg production factors, hatchability, and size, shape, and color of eggs, through the annual introduction of new blood from reliable sources but without pedigree breeding. The results show that this is possible, and that success will depend on the following factors:

1. The care with which the foundation flock is selected.
2. The ability to obtain new blood that will raise the level of the factors sought.
3. The elimination of undesirables before the breeding season begins.
4. The persistency with which the details of the program are followed.

The cost of this method of flock improvement is insignificant compared with the cost of pedigree breeding, as 300 eggs purchased annually will supply breeding males for a flock of 750 females and will also add a possible 100 to 125 quality pullets to the flock.

326 Naphthalene as a Greenhouse Fumigant. W. D. Whitcomb. 32 pp. illus. December 1935.

Naphthalene fumes may be used to kill certain greenhouse pests, particularly the common red spider, which are not controlled by the standard fumigating materials containing nicotine or hydrocyanic acid gas. Experiments in the greenhouse at the Waltham Field Station furnish the basis for specific information regarding the action of naphthalene fumes on various insects and plants, the conditions under which greenhouse fumigation with naphthalene is both safe and effective, estimates of cost, and directions for fumigating.

Control Bulletins

77 Seed Inspection. F. A. McLaughlin. 66 pp. February 1935.

78 Fifteenth Annual Report on Eradication of Pullorum Disease in Massachusetts. Poultry Disease Control Laboratory. 12 pp. July 1935.

79 Inspection of Commercial Feedstuffs. Philip H. Smith. 56 pp. September 1935.

80 Seed Inspection. F. A. McLaughlin. 66 pp. November 1935.

81 Inspection of Commercial Fertilizers. H. D. Haskins. 48 pp. December 1935.

82 Inspection of Agricultural Lime Products. H. D. Haskins. 8 pp. December 1935.

Meteorological Bulletins

553-564, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. C. I. Gunness. 4 pp. each.

Reports of Investigation in Journals
(Numbered Contributions)

175 The Toxicity of Aluminum on Seedlings and the Action of Certain Ions in the Elimination of the Toxic Effects. Walter S. Eisenmenger. Plant Physiol. 10 (No. 1): 1–25. 1935.

186 The Distribution of Roots in Porous and Non-Porous Plant Containers. Linus H. Jones and Henri D. Haskins. Plant Physiol. 10:511–519. 1935.

188 The Phosphorus Requirement of Dairy Heifers. J. G. Archibald and E. Bennett. Jour. Agr. Research 51:83–96. 1935.

197 The Relative Precipitating Value of Alcohols on Protein Solutions. Walter S. Eisenmenger. Kolloid-Zeitschrift 70 (1): 94–96. 1935.

198 Vitamin C Content of Twenty-One Massachusetts Grown Varieties of Apples. George G. Smith and Carl R. Fellers. Amer. Soc. Hort. Sci. Proc. 31: 89–95. 1934.

199 Effect of Fertilization, Freezing, Cooking, and Canning on the Vitamin C and A Content of Asparagus. C. R. Fellers, R. E. Young, P. D. Isham, and J. A. Clague. Amer. Soc. Hort. Sci. Proc. 31:145–151. 1934.

200 Comparison of Laboratory and Practical Tests in Determining the Nutritive Value of Fish Meals. M. M. Cleveland and C. R. Fellers. Amer. Fisheries Soc. Trans. 64 (1934): 293–303. 1935.

202 Vitamins C and A in Maple Products. C. R. Fellers and G. G. Smith. Amer. Soc. Hort. Sci. Proc. 31:96–97. 1934.

203 Bio-Assay of Vitamin D Milk. Carl R. Fellers. Mass. Milk Inspectors' Assoc. 28th Anniversary, 1st Annual Yearbook: 12–14, 33. 1935.

204 The Life-Time Yield of an Apple Orchard. J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 31:35–38. 1934.
Some Experiences with the Thornton Test for Potash in Apple Trees. J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 32:56–60. 1934.

205 Yield and Chemical Composition of Certain Species of Grass. J. G. Archibald and E. Bennett. Jour. Agr. Research 50 (No. 8): 711–715. 1935.

208 A Method for the Determination of Relative Stiffness of Cream During the Whipping Process. W. S. Mueller. Jour. Dairy Sci. 18 (No. 3): 177–180. 1935.

210 The Toxicity of Some Nitrogen Fertilizers and Other Compounds for a Species of Moss Common to Pastures of the New England States. A. B. Beaumont. Jour. Amer. Soc. Agron. 27 (No. 2): 134–137. 1935.

211 Toxicity of Aluminum Salts to Tobacco Plants. Walter S. Eisenmenger. Jour. Agr. Research 51 (No. 10): 919–924. 1935.

212 The Effect of Magnesium Deficiency on Crop Plants. A. B. Beaumont and M. E. Snell. Jour. Agr. Research 50 (No. 6): 553–562. 1935.

213 Progeny of Inbred and Non-Inbred Males in Rhode Island Reds. F. A. Hays. Poultry Sci. 14 (No. 2): 122–125. 1935.

214 The Etiology of Epidemic Colds in Chickens. Charles S. Gibbs. Science 81: 345–346. 1935.

215 Value of Commercially Canned and Laboratory-Prepared Tomato Juices as Antiscorbutics. C. R. Fellers, J. A. Clague, and P. D. Isham. Jour. Home Econ. 27 (No. 7): 447–451. 1935.

217 An Inexpensive Type of Construction for Concrete Tanks for Soil Investigations. A. B. Beaumont. Jour. Amer. Soc. Agron. 27 (No. 6): 497–498. 1935.

218 Ultrafiltration Experiments with the Viruses of Laryngotracheitis and Coryza of Chickens. Charles S. Gibbs. Jour. Bact. 30 (No. 4): 411–417. 1935.

220 Effect of Storage, Freezing and Canning on the Nutritive Value of Vegetable Products. C. R. Fellers and P. D. Isham. Veg. Growers Assoc. of Amer. Ann. Rpt.: 85–97. 1935.

222 Vitamin Content of Important Foods in the Child's Diet. Carl R. Fellers. Amer. Jour. Pub. Health 25: 1340–1345. 1935.

227 Red Squill Investigations: Properties, Toxicity, and Palatability of Red Squill and Powder Baits to Rats. M. G. O'Connor, R. E. Buck, and C. R. Fellers. Indus. and Engin. Chem. 27: 1377. 1935.

228 Red Squill Investigations: Effectiveness of Red Squill Extracts as Raticides. Robert E. Buck and C. R. Fellers. Indus. and Engin. Chem. 27: 1497. 1935.

Other Contributions to Journals
(Unnumbered)

Important Considerations in the Control of the Diseases of Greenhouse Vegetables. E. F. Guba. Veg. Growers Assoc. of Amer. Ann. Rpt.: 251–258. 1935.

Insect Pests of Massachusetts Orchards, 1934. A. I. Bourne and W. D. Whitcomb. Mass. Fruit Growers' Assoc. Ann. Rpt. 1935.

Notes on Insects Pollinating Onions. A. I. Bourne and F. R. Shaw. Jour. Econ. Ent. 28: 836–837. 1935.

Foods and the Economic Crisis. Carl R. Fellers, Chairman, Committee on Foods. Amer. Pub. Health Assoc. Yearbook 1934–35: 58–61. 1935.

Canned Maple Syrup. C. R. Fellers. The Canner 80: 13–14. April 20, 1935.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 328 March 1936

Heavy Mulching in Bearing Apple Orchards

By J. K. Shaw and L. Southwick

Various types of mulching are common practices in orchard management for the purpose of conserving plant food and soil moisture. Fifteen years of observation and experience with mulches are here reported and interpreted.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

The orchard practice of applying sufficient poor hay or similar material to suppress the growth of grass and weeds over most of the soil occupied by the tree roots keeps the soil a little cooler in hot weather and warmer in cold weather, conserves soil moisture in dry periods, and after the first two years furnishes plenty or an excess of soil nitrates. This excess seems not to interfere with satisfactory performance of the trees.

There can be little doubt that such an abundance of mulching material will supply sufficient soil nutrients other than nitrogen. It prevents soil erosion and must favor the absorption of rainfall by the soil. The normal top-root ratio of the tree is not disturbed.

This system may be rather expensive under some conditions; the cost will vary greatly but the work can be done over a considerable period of time, possibly when other work is not so important.

The amount of air-dry material necessary to bring about these conditions seems to be not much less than one pound per square foot per year for the area actually covered. It is possible that a somewhat smaller amount would give quite satisfactory results.

Mulching is most advisable under certain conditions: (1) where there is a convenient and cheap source of material, (2) on comparatively steep slopes, (3) on rough, stony land, (4) on loose, gravelly soils likely to suffer from lack of water during dry periods, (5) for varieties apt to drop heavily near harvest time, and (6) where root injury from cold is feared.

The possible objections are: (1) cost, (2) danger of fire, and (3) danger of injury from mice.

HEAVY MULCHING IN BEARING APPLE ORCHARDS

By J. K. Shaw, Research Professor of Pomology, and L. Southwick, Technical Assistant in Pomology

Apple orchards in Massachusetts are managed under various systems of culture. Some are cultivated, with a cover crop, either seeded or of weeds, allowed to grow through the latter part of the season. Many are in sod, the grass in most cases cut and left in the orchard but occasionally harvested and used for feeding purposes. In a few orchards various kinds of mulching materials grown elsewhere are brought into the orchard and spread under the trees. All sorts of modifications and combinations of these systems may be found.

The amount of brought-in material in mulched orchards varies greatly. This practice is meeting with increasing favor. If there is enough mulch, grass and weeds are more or less completely suppressed and do not rob the trees of moisture and plant nutrients. There is also less loss by drainage and there may be less runoff of rainfall. The root system of the trees is not disturbed as it is under cultivation. This system would seem to supply excellent conditions for vigorous growth of the trees and satisfactory production. Were it not for the difficulty of obtaining sufficient material and the labor and expense involved, mulching might be generally recommended as an excellent system of soil management for orchards.

Review of Literature

Stewart of Pennsylvania Station reported in 1915 (10), the effects of cultural methods on tree growth. The soil was a glaciated, Volusia silt loam and was planted in 1908. Mulching "to prevent any appreciable growth of vegetation immediately over the majority of the tree roots" was compared with tillage and cover crops, tillage and intercrop, and tillage alone as methods of culture. The author concluded that "orchard tillage is simply to be regarded as preferable to sod or to the presence of other untilled intercrops, but that it is not equal to a definite mulch either in moisture conservation or in promoting the growth of young trees."

However, working with more mature orchards, he found some "reversals of previous forms" not so much in regard to yield as in regard to growth. The soil was a sandy loam and the trees (Baldwin and Spy) were thirty-six years of age at the start of the experiment in 1907. On the mulched plots, annual applications of swamp hay at the rate of about three tons per acre plus the intergrowth (which was light) were made. Yield and growth of the trees on these mulch plots were compared with yield and growth of the trees grown under the ordinary cultivation – cover crop system. When no fertilizer was given in these experiments, average growth and annual yields were greater under tillage and cover cropping. But where either manure or commercial fertilizer was added in definite amounts to both systems of culture, the mulched trees outyielded the cultivated. Nevertheless the latter maintained superiority in growth as measured by trunk girth in all trials.

In 1916, the same investigator (11) reported results of these and four other experiments in bearing orchards in different parts of the state, the orchards ranging in age from 6 to 36 years at the start of the experiments. His conclusion follows: "In general the mulch treatment, reinforced by outside materials, has been most efficient in improving the yield, growth, and average size of fruit in orchards up to about twenty years of age. In older orchards, it has been surpassed slightly by tillage and cover crops, unless accompanied by adequate fertilization. It has also been most efficient in conserving moisture, in all cases that have been determined."

The experiments of Green and Ballou (7), Ellenwood (5), and Wiggans (12) showed favorable results from mulching, but these experiments dealt with young trees while we are concerned here with trees of bearing age. Somewhat approaching this specifically designated field are the orchard soil management studies of Cullinan and Baker (4) in Indiana. Even here, however, treatment of young trees is of major importance. The study concerned the effects of tillage with cover crop, straw mulch, and sod on the growth and production of Grimes, Jonathan, and Stayman apple trees. The study covered a fifteen-year period and was begun after the trees had grown one year in the orchard. It was found that the trees receiving a heavy mulch were "nearly equal" to the trees under cultivation. However, a statement closely following this observation should be borne in mind. "We are not certain that the amount of straw used on Plot C constituted an adequate mulch." This is a very important consideration, especially when this plot was just as productive, over a ten-year period as the trees under cultivation and further maintained a more uniform yearly production. With a substantial increase in the amount of mulch material used, the growth and production of the mulched trees might well have exceeded the "nearly equal" comparison with cultivation.

At the Missouri State Fruit Experiment Station at Mountain Grove (6) comparative tests of straw mulching and other common methods of soil management by Faurot revealed that in yield, trunk circumference, and growth of head the straw mulch plots were outstanding. One orchard was set in 1902 and the other in 1921. The findings thus support the theory that mulching as an orchard soil management practice is equally suitable for young or mature orchards; i.e., if mulching material is already available or is procurable at low cost. However, Faurot deemed it unwise to advocate mulching for commercial orchards "because of scarcity of straw and more because of possible fire hazard."

Experimental Work

In 1921 the Experiment Station took over two orchard blocks of approximately two-thirds acre each. One block was planted to 18 McIntosh trees, 40 feet apart, and the other to 18 Wealthy on seedling roots 40 feet apart and interplanted with Wealthy on Doucin stock. These stocks proved to be Malling V, the Improved Doucin. These dwarf trees were removed in the fall of 1932.

The trees had been planted in 1911 and were originally interplanted with dwarf Wealthy on Paradise roots, pears, and currants. For a few years the orchards were intensively cultivated and probably well fertilized. Later, during the war and immediately after, they were somewhat neglected. The interplanted trees and bushes had been removed before 1921. The remaining trees were in good vigor and were beginning to bear commercial crops.

These two adjoining plots lie on an easterly slope. Below, the land slopes gently easterly to swampy land that has since been tile drained. To the west, somewhat higher sloping land extends to the top of the hill about 300 feet away. The soil is a stony loam underlaid with a rather compact subsoil. It is probable that there is considerable seepage from the higher land through the orchard.

In the spring of 1922 the lower half of the McIntosh block and the upper half of the Wealthy block were mulched heavily with low-grade hay. This treatment has been continued with somewhat irregular applications of mulching material, gradually extending the mulched area as the trees grew, until now nearly all the surface is covered with material sufficient to prevent the growth of grass or weeds. No record has been kept of the weight of the applied mulch but it has probably been somewhere near a pound per square foot per year. This is probably more than would be advisable in practice. The lower layers are decayed and filled with fine fibrous roots. A few of the Wealthy trees were injured by mice but no more than in other orchards in sod. A space three to four feet in diameter around the trunks was excavated and filled with gravel and there has been no more mouse injury since. Poisoned grain has been placed in the orchard each fall in recent years.

The other halves of the plots have been under a cultivation – cover crop system.

No fertilizer has been applied to the mulched plots, and none to the cultivated plots until 1931 when the trees on these plots appeared to be losing vigor. Beginning in 1931 an annual application of 100 pounds of nitrate of soda has been made to each cultivated plot. Growth of the cover crop has varied in different years but has generally been small. It has been somewhat heavier following the use of nitrogen, but cannot have been enough to maintain the organic matter of the soil.

Conditions in the Soil

During the summers of 1925 and 1926 soil samples from each of the four plots were taken weekly during the growing season and at less frequent intervals up to January 15. The soil temperature was noted each time and a mechanical analysis of the soil was made. The results of this work have been reported by Beaumont and others (1, 2). Very fine sand predominates in the soil (33.8 percent). There is considerable silt (19.7 percent) and some clay (9.7 percent). Soil temperatures did not differ much according to soil treatment, but in midsummer the soil sometimes was one or two degrees cooler under the mulch. Soil moisture differed less than might be expected. In the Wealthy block the average was practically the same both years under the two treatments, while in the McIntosh block soil moisture was considerably higher under the mulch. This means that the location of the plots had more effect on soil moisture than the treatment. The mulched McIntosh and cultivated Wealthy plots were lower and were naturally more moist than the other two plots. The mulching overcame this difference in the Wealthy plots, while the natural difference in the McIntosh plots was increased. The moisture-conserving effect of the mulch was more apparent in dry periods in midsummer and may be more significant than the averages indicate. There was less fluctuation from week to week under the mulch.

The most astonishing result of these studies was the great accumulation of soil nitrates under the mulch. This has been reported by Beaumont (2). The general nature of his results is indicated in Table 1 which gives some averages for the McIntosh and Wealthy plots. Probably a seasonal average of 30 parts of nitrates per million parts of soil indicates a sufficient supply of nitrogen for the needs of the tree.

TABLE 1. — SOIL NITRATES UNDER CULTIVATION AND MULCH. (PARTS PER MILLION)

	1925		1926	
	Mulch	Cultivation	Mulch	Cultivation
Maxium	89	27	452	83
Minimum	12	1	29	Trace
Average	38	10	128	20

Not only were soil nitrates under the mulch very high during the growing season but they continued high during the fall and winter. In 1926 samples were taken at intervals up to January 15, 1927, when the average from the two mulched plots was 10 p.p.m. During November and December the six determinations of soil nitrates showed between 10 and 160 p.p.m.

During the years 1928–31 less extensive determinations of soil nitrates were made (1). In these years, while lower than in 1925–26, they were still much higher on the mulched than on the cultivated plots and continued high during August and September.

Determinations of soil nitrates under a similar mulch in another orchard on a similar soil, beginning with the first application of poor hay, showed no nitrates during the first season, very low nitrates during the second and third, and abundant nitrates during the fourth season. While no measure was taken in the McIntosh and Wealthy blocks during the early years of mulching, the appearance of the trees indicated a similar condition. No difference in foliage color was noted during the first two years of mulching, but the foliage was distinctly darker green in the third year and this difference continued until nitrate was applied to the cultivated plots in the ninth year of the experiment, since when there has been no noticeable difference in leaf color on the different plots.

The mulching material contained about 1 percent of nitrogen. In view of the large amounts applied, the nitrogen in the mulch is enough to account for the high nitrates found in the soil.

Growth of the Trees

The high soil nitrates continuing through the late summer and fall might be expected to bring about a growth of the trees indicative of a high-nitrogen – low-carbohydrate ratio, excessive growth, and a condition favorable to winterkilling. This is not the case. While there was considerable bark injury to McIntosh in Massachusetts during the winter of 1933-34, none was observed in this orchard. Neither have there been any signs of winter injury of the Wealthy trees. Terminal bud formation has taken place a little later on the mulched trees in some years.

Shoot growth measurements of the McIntosh trees on the mulched and cultivated plots were taken at 10-day intervals during the 1927 growing season. Growth started on the mulched and cultivated plots at about the same time, and the first measurements were taken ten days after the shoot growth started. When the last measurements were taken, 95 percent of the measured shoots on the mulched plots and only 40 percent of the shoots on the cultivated plots had formed terminal buds.

TABLE 2. — PROGRESS OF SHOOT GROWTH ON McINTOSH TREES, 1927. (CENTIMETERS)

	Mulch	Cultivation
May 26	8.7	7.6
June 6	6.2	5.6
June 17	5.0	4.9
June 28	1.4	1.5
July 9	0.1	0.3
Total	21.4	19.9

While the shoots on the mulched trees grew more this year, they formed terminal buds earlier. This was not true every year. Measures of annual shoot growth have been made, generally every three years, measuring four seasons' growth each time. These give the picture shown in Figure 1. Shoot growth was generally greater on the mulched plot until nitrogen was applied to the cultivated plot in 1931, but there has been little difference since. The shoot growth of the trees on the mulched plot exceeded that of the trees on the cultivated plot more in 1921, 1922, and 1923 than it did in most later years. In these earlier years it is very doubtful if any nitrogen from the mulch had become available to the trees. Possibly the mulched trees had a better moisture supply. In no year has shoot growth on the mulched trees been excessive. There is a slight negative correlation between size of crop and shoot growth the succeeding year, but there is little or none between size of crop and shoot growth the same year. No measures of shoot growth of the Wealthy have been made because of the terminal bearing habit of this variety.

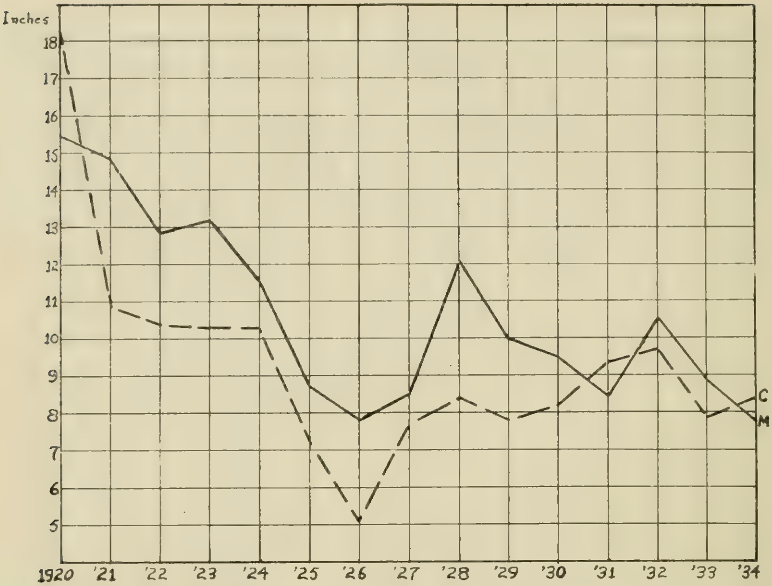


Figure 1. Average Annual Shoot Growth, McIntosh.
M—mulched plot C—cultivated plot

Trunk diameter measurements have been taken each year except 1934. The averages for each plot are shown in Table 3.

The McIntosh trees have grown most, followed by the Wealthy on seedling stocks and Wealthy on Doucin stocks. The initial differences in 1921 before differential treatments were begun are important. In each case the trees on the mulched plot were larger than those on the cultivated plot, and the same is true at the last measurement. Both varieties have made more trunk growth on the mulched plots. The rather small differences here shown signify considerable differences in the size of the crown and therefore the bearing area, as shown later.

There is a close correlation between trunk growth and crop; in years of heavy crop, trunk growth is small. This is clearly shown in the Wealthy trees. The annual trunk increase in millimeters is as follows: 6, 13, 8, 9, 6, 12, 7, 13, 5, 13, 2, 15. The smaller figures represent growth in the crop years.

The most significant figures in this table from the point of view of this comparison are the percentage differences between the mulched and cultivated trees. The differences are comparatively small in the case of Wealthy, but there is a steadily increasing difference in the case of McIntosh until after the nitrate of soda was applied to the cultivated trees when there was a slight decrease as would be expected. The differences between the mulched and cultivated McIntosh trees are probably due in part to more favorable natural conditions on the mulched plot, but one cannot escape the conclusion that mulching has favored growth. Had the cultivated plots been fertilized during the entire period, the difference would have been less and might have been reduced to that due to natural soil conditions.

TABLE 3. — AVERAGE TRUNK DIAMETERS.
(MILLIMETERS)

	McINTOSH			WEALTHY, STANDARD			WEALTHY, DOUCIN		
	Mulch	Cultivation	Percentage Difference	Mulch	Cultivation	Percentage Difference	Mulch	Cultivation	Percentage Difference
1921......	147	142	4	119	116	3	93	76	22
1922......	168	161	4	125	121	3	99	82	21
1923......	184	174	6	138	132	4	109	89	22
1924......	202	188	7	146	143	2	114	96	19
1925......	228	205	11	155	154	1	123	104	18
1926......	247	221	12	161	165	–2	129	111	16
1927......	263	235	12	173	175	–1	140	119	18
1928......	278	244	13	180	182	–1	146	122	20
1929......	292	259	13	193	193	0	156	130	20
1930......	306	268	14	198	198	0	161	133	21
1931......	323	279	16	211	209	1	167	139	20
1932......	331	287	15	213	211	1	171	142	20
1933......	351	306	15	228	227	0			
1934......	No record								
1935......	378	334	15	252	246	2			
Total Growth.	231	192	12	133	130	2	78	66	18

Table 4 shows that the size of the crown varies much as trunk diameter and shoot growth; and with the exception of spread of Wealthy, all the measurements show the mulched trees to be larger. This is especially true of volume (8). While the method of calculation does not show exactly the tree volume nor the bearing area, it should show the differences between the two lots of trees. The volume of the cultivated McIntosh is 72 percent and of the cultivated Wealthy 84 percent of the volume of the mulched trees.

TABLE 4. — SIZE OF CROWN, 1935.

	McIntosh		Wealthy, Standard	
	Mulch	Cultivation	Mulch	Cultivation
Height, feet	24.9	22.4	20.1	18.6
Spread, feet	38.2	34.3	25.5	26.2
Volume, cubic feet*	9298	6680	3403	2871

*$V = \left(\frac{S}{2}\right)^2 H$. V = volume, H = height, S = spread.

Yield of Fruit

The yield of apples is of the most interest to the fruit grower. These are shown in Figure 2 and Table 5.

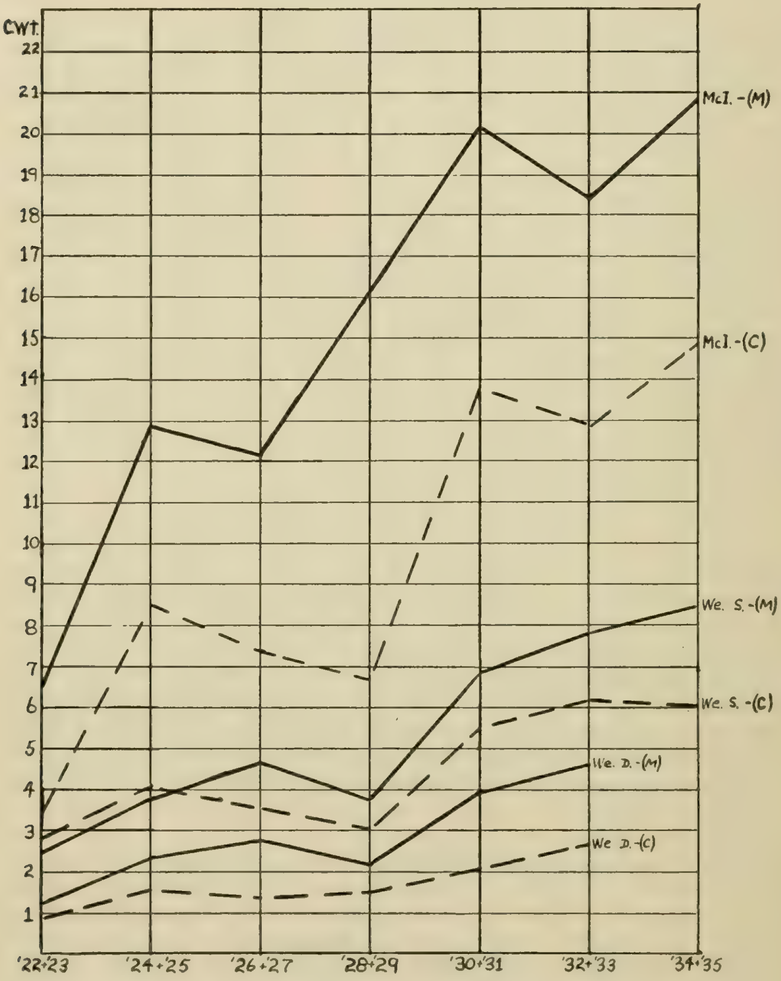


Figure 2. Average Annual Yields, by Two-Year Periods, Pounds per Tree.
McI.—McIntosh We. S.—Wealthy, Standard We. D.—Wealthy, Doucin
M—mulched plot C—cultivated plot

The Wealthy trees have been distinctly biennial in bearing habit all through the period under discussion, and the McIntosh trees have shown some tendency in this direction especially during the last six years. In order to offset this and make a clearer picture of the general tendency, the yields are shown in the figure by two-year periods in average pounds per tree.

Considering McIntosh during the first six years, the trees in cultivation yielded less than the mulched trees and there is a tendency towards a widening of this difference which is marked in the next biennium, 1928–29. It was this that suggested the necessity of applying nitrogen to the cultivated plots if yields were to be maintained. The use of nitrogen on the cultivated plot was followed by a sharp increase in yield which was made more striking by the heavy crop in 1930 when the trees were still unfertilized but which was a heavy crop year when all sorts of trees bore unusually heavy crops. In these last six years the lines are nearly parallel and suggest that had the cultivated plots been fertilized during the entire period, the yields might not have been so far apart.

In the case of Wealthy on standard stocks, the yield on the cultivated plot was larger at the start but soon fell below that on the mulched plot. There is no striking response from the nitrogen applied in 1931, as the yield on this plot increased no more than that on the mulched plot where there was no change of treatment. In fact there is a falling off in the last biennium. The same is true of Wealthy on Doucin stocks, except that the yield on the cultivated plot has been lower all the time. It has been shown that there has been a great excess of nitrates in the mulched plot, and it may be that nitrates in the drainage water passing down the slope on the compact subsoil have supplied the trees in the cultivated plot with the required nitrogen.

Many fruit growers may find it easier to think in terms of bushels per acre than to read a graph. In Table 5 the average annual yields in pounds per tree have been converted into bushels per acre. A unit of a 50-pound bushel has been used, although a bushel of these varieties weighs around 45 pounds or less. The yield records include all fruit on the ground, some of which is worthless, and it is thought that a 50-pound bushel gives a fairer basis of compilation. In choosing the number of trees per acre, McIntosh yields are computed on the basis of 27 trees per acre, or approximately 40 x 40 feet, the distance at which they stand in this orchard. The standard Wealthy yields are computed on the basis of 35 trees per acre or approximately 35 x 35 feet and the Doucin Wealthy at 108 trees per acre or 20 x 20 feet. Actually, the standard trees were 40 x 40 feet interplanted with the dwarf trees bringing the distance to 20 x 20 feet.

This table shows the tendency for the McIntosh to alternate following the heavy crop of 1930 and the distinct alternation of the Wealthy trees during the entire period. The larger acre yields of the dwarf trees should not be taken too seriously, as the planting distances assumed are arbitrary and a change would alter the figures. However, the assumed distances are reasonable, and the figures indicate that a dwarf Wealthy orchard on this particular stock (Malling V) might be expected to yield at least as well as the usual kind of trees.

No data concerning the size or quality of apples produced under the two types of soil management have been collected, but observation indicates little difference. Apples from the mulched plots have been slightly later in maturing in some years; the green undercolor has been a little slower in developing. There has been little difference in the red coloration. The dwarf Wealthy trees have produced somewhat smaller apples than those on seedling roots.

TABLE 5. — AVERAGE YIELDS PER ACRE.
(BUSHELS)

	McIntosh		Wealthy, Standard		Wealthy, Doucin	
	Mulch	Cultivation	Mulch	Cultivation	Mulch	Cultivation
1922	100	56	172	191	270	171
1923	254	130	4	4	6	24
1924	322	237	241	262	470	315
1925	374	220	22	20	45	19
1926	297	171	295	217	518	240
1927	368	229	32	32	73	50
1928	380	195	234	176	432	272
1929	494	168	27	34	43	48
1930	723	491	411	328	730	343
1931	373	252	72	60	125	97
1932	684	524	515	401	892	475
1933	312	172	28	33	–	–
1934	737	617	571	407	–	–
1935	391	185	20	14	–	–
Average	415	261	189	155	328	187

TABLE 6. — AVERAGE PERCENTAGES OF CROP DROPPING PREMATURELY.

	McIntosh		Wealthy, Standard		Wealthy, Doucin	
	Mulch	Cultivation	Mulch	Cultivation	Mulch	Cultivation
1924–27	23	13	19	9	12	9
1928–31	34	17	27	15	19	13
1932–35	36	25	35	21	24*	20*
1922–35	29	17	26	17	16‡	12‡

*1932 only. ‡1922–32.

Records of the weight of fruit dropping prematurely have been kept for the entire period and are summarized in Table 6. This includes all the fruit falling later than the June drop and therefore some fruit not salable. Varying dates of picking and the occurrence of winds just before harvest in some years have doubtless had some effect. With McIntosh the average percentage of drop in different years has varied from 5 to 60 percent and with Wealthy from 0 to 54 percent. The table shows that dropping has been more severe on the mulched than on the cultivated plots and has increased with the age of the trees. It is less on the Dwarf than on the Standard Wealthy trees. Examination of the records shows that there is no relation between the size of the crop and the percentage of dropped fruit — a light crop may drop as badly as a heavy crop. The amount of drop is plainly greater in certain years, among which 1935 shows the heaviest drop; while 1932 shows the least of any recent year. Despite the heavier drop on the mulched plots the amount of picked fruit has been greater each year than on the cultivated plots.

Discussion

The data presented seem to show that the mulched trees have grown and produced better than those under cultivation. On most soils, however, trees will not perform well without fertilization for very many years even under cultivation. If the cultivated plots had been well fertilized for the entire period the trees might have grown and yielded as well as the others. It is reasonable to believe that the differences would have been less than those recorded. The most that can be said is that this experiment indicates that trees heavily mulched so that there is little or no growth of grass and weeds may be expected to give a good account of themselves.

There are some strong arguments in favor of mulching.

1. It absolutely prevents erosion of the soil covered; this is extremely important especially when we take a long look ahead.
2. Soil moisture will be conserved; there will be little or no runoff during heavy rains and less evaporation from the soil. In other words there will be increased absorption and less loss to the atmosphere.
3. The soil will doubtless be warmer in the winter; this may prevent root killing during severe cold periods and favor root activity during the late fall and winter.
4. There will be less injury to apples dropping prematurely; they will be cleaner than if they dropped on cultivated soil and less likely to be bruised by stones or stubble.

The principal argument against mulching is the cost. In most cases, cost is largely that of labor. If one estimates labor at current rates, mulching will cost more than other common systems of soil management, especially in view of the present low prices of nitrogen and potash, the two fertilizer elements drawn upon most heavily by the apple crop. However, the labor involved in mulching can be spread over a long period and may be done when the fruit grower can find no very profitable employment. The cost of mulching will vary greatly under different conditions.

Another possible objection is the danger of injury from mice and fire. It would seem advisable to place five or six inches of coarse gravel around each tree over a space three or four feet in diameter and to conduct a vigorous campaign for the eradication of mice in the orchard. In several years' experience at this station no tree protected with gravel has been injured by mice, but this is not saying that injury will never occur. The injury to trees from fire in the orchard is seldom as severe as it appears immediately following the burning. The mulch should certainly be kept well away from the tree trunks so that a fire may not kill the bark. If the lower branches only are killed, the tree will soon recover. However, one can hardly escape the fear that if fire ran through such a heavy mulch as is here described the damage would be great. A desirable precaution would be to plow strips through a mulched orchard so as to divide it into relatively small blocks which would give a chance to check a possible fire.

Summary

1. McIntosh and Wealthy apple trees were observed during a fifteen-year period under a comparison of heavy mulch and cultivation with a cover crop. No additional fertilizer was used on the mulched plots; the cultivated plots received nitrate of soda at the rate of 300 pounds per acre during the last six years only.

2. The moisture content of the surface layer of soil differed little except during dry periods when it was higher under the mulch.

3. Soil temperature during the growing season differed little except during warm periods when it was a little lower under the mulch.

4. After the first three years the soil nitrates were much higher under the mulch, rising to a maximum of over 400 p.p.m. They continued high during the fall and early winter.

5. This excess of soil nitrates did not produce excessive growth of the trees.

6. Growth and yield of the trees was greater under the mulch system than under cultivation. The application of nitrate of soda to the cultivated plots was followed by increased growth and higher production with McIntosh, but with Wealthy the increase was small.

7. Fruit on the mulched trees matured a little later, but no marked differences in color or quality were observed.

8. Some of the Wealthy trees were on Doucin stock, identified as Malling V. On an assumed acre basis these trees produced more heavily than those on standard seedling stocks. The apples were a little smaller.

9. Premature dropping was greater on the mulched trees and increased with the age of the trees. It varied greatly in different seasons. The percentage dropping was not greater in heavy crop years. Wealthy trees on Doucin stocks dropped less than those on standard stocks.

10. This work suggests that heavy mulching is a satisfactory system of orchard management. The chief objection is cost. Under certain conditions it may be a desirable system.

References

1. Beaumont, A. B., and G. C. Crooks. The Influence of a Mulch on Soil Nitrates. Soil Sci. 36: 121–123. 1933.
2. Beaumont, A. B., A. C. Sessions, and O. W. Kelly. Nitrate Accumulation under a Mulch. Soil Sci. 24: 177–185. 1927.
3. Blake, M. A. Amount of Mulch Material Required by Apple Trees. N. J. Agr. Expt. Sta. Circ. 286. 1933.
4. Cullinan, F. P., and C. E. Baker. Orchard Soil Management Studies.

Ind. Agr. Expt. Sta. Bul. 315. 1927.

5. Ellenwood, C. W. Cost of Growing Apple Trees under Tillage and Grass-Mulch Management. Ohio Agr. Expt. Sta. Monthly Bul. 109 and 110: 7–13. 1925.
6. Faurot, F. W. Orchard Soil Management. Mo. State Fruit Expt. Sta. Bul. 28. 1934.
7. Green, W. J., and F. H. Ballou. Orchard Culture — A Comparison of Different Methods as Applied in the Care of the Apple Orchard. Ohio Agr. Expt. Sta. Bul. 171. 1906.
8. Hedrick, U. P., and R. D. Anthony. Twenty years of Fertilizers in an Apple Orchard. N. Y. Agr. Expt. Sta. Bul. 460. 1919.
9. Moore, W. J., Jr., and A. B. Beaumont. The Relation of the Carbon-Nitrogen Ratio of a Mulch to the Accumulation of Nitrates in Soil. Jour. Amer. Soc. Agron. 26 (No. 3): 252. 1934.
10. Stewart, John P. Results from Experiments on Cultural Methods, Cover-Crops and Fertilization in Apple Orchards. Pa. State Coll. Ann. Rpt. 1913–14 (Pt. 2): 423–438. 1915.
11. Stewart, John P. Cultural Methods in Bearing Orchards. Pa. Agr. Expt. Sta. Bul. 141. 1916.
12. Wiggans, C. B. A Study of the Effect of Certain Fertilizer and Cultural Treatments upon the Vigor of Young Stayman Apple Trees. Ark. Agr. Expt. Sta. Bul. 254. 1930.

Publication of this Document Approved by Commission on Administration and Finance
5m. 3–'36. No. 7163.

146
2
329

VIRGINIA POLYTECHNIC INSTITUTE
AGRICULTURAL BRANCH LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 329 March, 1936

Winter Pause In Rhode Island Reds

By F. A. Hays

Many pullets stop laying for four or more successive days during the winter months. These nonproductive periods cause considerable economic loss which is becoming more serious as higher levels of egg production are being attained. This report is part of an attempt to develop methods for the control or elimination of winter pause.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

WINTER PAUSE IN RHODE ISLAND REDS

By F. A. Hays, Research Professor of Poultry Husbandry

A cessation of laying for four or more successive days during the winter months of the pullet year is called a winter pause in this report. The time limits considered lie between November 1 and March 1. These periods of nonproduction are of great economic importance. Some years ago Hays and Sanborn (1926) showed that nonpause birds averaged to lay 16 more eggs in the pullet year than pause birds. As new high levels of egg production are being attained by selective breeding, the control of the winter pause becomes even more important. Difficulties in separating the effects of inheritance from the effects of environment upon winter pause have been pointed out many times by this laboratory. This is a report of a further attempt to discover factors that may affect winter pause so that methods may be worked out for its control or elimination.

The birds used in these studies include production-bred Rhode Island Reds used in different experiments. The birds used in section 4 were hatched in 1926 and represent the last flock on which hourly trapnest records are available. The birds used for study in all of the other sections were hatched in 1933 and 1934.

1. Hatching Date and Winter Pause

Date of hatching is known to have a definite effect on pause duration. Within recent years there has been an ever-increasing amount of early hatching, so that many pullets are hatched in February or March. With this early hatching, production-bred pullets that normally begin laying at about six months of age will begin their laying year in August. Observations indicate that the great majority of these birds will stop laying before March 1 and many will undergo a partial molt.

The relation between hatching date and presence or absence of pause and the effect of hatching date on pause duration were studied in a total of 1,006 pullets hatched in eight weekly hatches between March 4 and April 23 in 1933 and 1934. Winter pause appeared in the following percentages of birds in the eight hatches: Hatch 1, 76.9; hatch 2, 77.0; hatch 3, 75.3; hatch 4, 81.5; hatch 5, 68.2; hatch 6, 64.4; hatch 7, 59.4; and hatch 8, 55.9. Apparently the proportion of birds that exhibit pauses of four or more days was less in the April hatched pullets than in those hatched in March.

In order to determine the relation between hatching date and pause duration, the coefficient of correlation was calculated on the 693 individuals with winter pause. The regression of pause duration on hatching date was found to be strictly linear by Blakeman's test. The constants obtained are as follows:

Number of birds	693
Mean hatching date	March 29
Hatching date standard deviation, days	±15.19
Mean pause duration, days	37.11
Pause standard deviation, days	±24.31
Coefficient of correlation	−.2366 ± .0242

The standard deviation in hatching date was high because about the same number of birds was included in each hatch. The mean pause duration in this population, made up entirely of birds with pause, was about 37 days. This is a long period of nonproduction occurring at a time when birds in production are laying at a high rate. Economically, this cessation of production is very important because egg prices are likely to be high in winter. The pause standard deviation is extremely high and the actual range in pause duration was from 4 to 123 days.

The coefficient of correlation measuring the association between hatching date and duration of pause is of some significance. Its squared value, however, indicates that less than 6 percent of the variation in length of pause is due to differences in hatching date. The conclusion must be drawn from these data that the range in hatching dates considered had very little effect on pause duration, and that other factors of greater importance must have been operating. Taken by hatches, there was an average decline in length of pause of about 20 days between the first and the last hatches.

2. Age at First Egg and Pause Duration

Hays and Sanborn (1926) reported a correlation of –.2329 ± .0138 between age at first egg and pause duration. This constant was obtained on 2134 birds hatched between March 25 and May 15. In the present study the hatching dates were three weeks earlier. It would seem probable from these earlier studies that laying at an early age might increase the length of pause. It should be noted that the mean age at first egg of the birds previously reported was 203 days while the mean age of the birds in this study was 190 days. The 693 birds with pause were tabulated and the following constants obtained:

Number of birds	693
Mean age at first egg, days	190.30
Age standard deviation, days	±21.76
Mean pause duration, days	37.11
Pause standard deviation, days	±24.31
Coefficient of correlation	–.0323 ± .0256

The regression of pause duration on age at first egg was found to be linear by Blakeman's test. The coefficient of correlation was of insignificant magnitude, suggesting no relation between age at first egg and duration of pause. The percentage of birds with pause in the earlier report was lower than in this study, the means in the two groups being 63 percent and 69 percent, respectively. Apparently earlier hatching has overcome the relation between age at first egg and pause duration that was observed in the earlier studies.

3. Weight at First Egg and Pause Duration

Poultrymen often express the view that pullets may stop laying during the winter season because they lack sufficient reserve to keep laying throughout the winter. Reserve is difficult to measure, but the assumption might be made that heavy body weight is an indication of reserve. Hays and Sanborn (1926) found no correlation between body weight at first egg and duration of winter pause. Since no other measure of reserve has been suggested, however, the coefficient of correlation between body weight at first egg and pause duration has been calculated for the birds in this study.

Number of birds	692
Mean weight at first egg, pounds	5.90
Weight standard deviation, pounds	±.60
Mean pause duration, days	37.14
Pause standard deviation, days	±24.32
Coefficient of correlation	+.0836±.0255

The mean weight was very satisfactory and the variation in weight was not excessive, since the coefficient of variation was about 10 percent. The coefficient of correlation is so small that it indicates no significant relation between weight and pause duration. These data indicate that pullets that are heavy when they lay their first egg are likely to pause just as long as lighter-weight birds. Body weight at first egg cannot, therefore, be used as an indicator of a pullet's probable ability to lay continuously throughout the winter.

4. Time Interval Between Eggs and Winter Pause.

The rate of laying depends in large measure upon the time interval between eggs of the same clutch during any particular time, as Hays (1936) has pointed out. It is desirable to know also whether the mean time interval between eggs during the months from October to February of the pullet year shows any relation to the presence or absence of winter pause or to pause duration in birds with pause. Hourly trapnest records are available only on the flocks hatched up to 1926; consequently the 1926 flock of 462 birds was chosen for this study.

The data for each of the five months considered are presented in table 1. The table shows that the time interval between eggs increased through the winter months from 25.78 hours in October to 27.43 hours in February.

TABLE 1. — TIME INTERVAL BETWEEN EGGS AND WINTER PAUSE

	Mean Time Interval Hours	Total Birds	Nonpause Birds Percent	Mean Pause Duration* Days
October	25.78	126	16.67	38.40
November	26.40	305	23.93	29.45
December	26.80	434	29.49	26.41
January	27.33	453	30.68	26.05
February	27.43	462	30.74	27.34

*Only birds with pause included.

Freedom from winter pause did not increase or decrease regularly with the time interval change in any of the five months considered. There was, however, a tendency for the more rapid layers to show a greater degree of freedom from pause. The group of birds having a time interval of 25.5 hours showed the highest percentage of nonpause birds in October and November. In December the 64 birds with a time interval of 27.5 hours were freest from winter pause; in January there was least winter pause in the 28-hour group; and in February the highest percentage of nonpause birds was in the 26.5-hour class.

The mean pause duration in the birds having winter pause fluctuated widely in the different time-interval classes. No consistent relation was observed, however, between time interval and pause duration in the five-month period. There is some evidence to indicate that rapid layers will pause for a shorter period than slow layers.

5. Winter Clutch Size and Pause Duration

The average winter clutch size between first pullet egg and March 1 has been used extensively as a measure of intensity. Clutch size has recently been shown by Hays (1936) to be intimately associated with the time interval between eggs within the clutch. It is desirable to know whether the rate of laying measured by clutch size affects the duration of winter pause. The coefficient of correlation was calculated and the regression was found not to be strictly linear. The constants are as follows:

Number of birds	693
Mean winter clutch, eggs	3.21
Clutch standard deviation, eggs	±1.31
Mean pause duration, days	37.11
Pause standard deviation, days	±24.31
Coefficient of correlation	−.1803 ± .0248
Correlation ratio	.2349

The population may be considered as made up of intense layers because a mean clutch size of 3.21 indicates that both genes for high intensity must have been present in the majority of birds. The magnitude of the standard deviation suggests, however, that clutch size fluctuates widely in the flock. Since the regression of pause duration and clutch size is not strictly linear, the correlation ratio must be used instead of the coefficient of correlation. This constant indicates a negative association amounting to .2349 and gives evidence that rapid layers are likely to pause for a shorter period than mediocre or slow layers.

6. Production Previous to Pause and Pause Duration

The assumption is sometimes made that winter pause may be a rest period following a considerable interval of heavy laying. If this were the case, greater length of pause should occur in the birds with highest previous egg records. In the previous section it has been shown that intense winter layers are likely to pause for shorter periods than mediocre layers, which indicates that rapid functioning of the reproductive organs does not deplete the pullet sufficiently to necessitate a long recuperative period. In order to discover the relation of previous egg production to pause duration, the coefficient of correlation was determined as the regression was linear.

Number of birds	693
Mean previous production, eggs	54.06
Production standard deviation, eggs	±29.80
Mean pause duration, days	37.11
Pause standard deviation, days	±24.31
Coefficient of correlation	−.2224 ± .0244

Mean egg production previous to the pause was high, considering the fact that the pause may begin as early as November. Variability in production at this time was very high as indicated by the standard deviation. The coefficient of correlation was negative, suggesting that an increase in number of eggs laid was not followed by a greater length of pause. The squared value of this constant shows that less than 5 percent of the variation in pause duration could be attributed to previous egg production. These data suggest that pause duration is not increased either by the number of eggs laid or by the rate of laying previous to the pause.

7. Length of Previous Production Period and Pause Duration

Early hatched pullets would normally go through a long period of egg laying before March 1. For this reason it is important to know whether the length of the production period previous to the winter pause affects the length of winter pause. Hays and Sanborn (1926, page 173) studied this question with Rhode Island Reds. Examination of their data shows that the regression of pause duration on length of previous production period is not linear. The data are as follows:

Number of birds	2,078
Previous production period, days	52.26
Production period standard deviation, days	±34.23
Mean pause duration, days	31.91
Pause standard deviation, days	±21.68
Coefficient of correlation	−.1385 ± .0145
Correlation ratio	.2199

The relation between length of the previous production period and winter pause duration, as measured by the correlation ratio, was .2199. The relationship was of a negative order, indicating a tendency for the pause to decrease in length as the previous production period increased. Certainly not more than 5 percent of the variation in pause duration was attributable to variation in length of the previous production period. It follows, therefore, that duration of pause was but little dependent upon the length of time that the pullets had been laying.

8. Production Following Pause and Pause Duration

If winter pause were a recuperative period, it is conceivable that pauses of greater duration might be followed by increased rate of laying and greater production for the remainder of the year. In order to discover the relation of egg production following the pause to duration of pause, the coefficient of correlation was calculated. The following constants were derived:

Number of birds	353
Mean production following pause, eggs	140.62
Production standard deviation, eggs	±40.56
Mean pause duration, days	34.62
Pause standard deviation, days	±23.08
Coefficient of correlation	−.0799 ± .0357
Correlation ratio	.2377

In the group of 353 birds that completed their first laying year, there was the rather high mean of about 141 eggs following the winter pause. The regression of pause duration on subsequent egg production was nonlinear. The correlation ratio of .2377, therefore, expresses the true relation. There was something of a tendency for birds with short pause to lay more eggs for the remainder of the year than did the birds with long pause. This further substantiates the idea that winter pause cannot be considered as a recuperative period enabling the pullet to begin laying at a higher rate than her nonpause sisters.

9. Winter Egg Production and Pause Duration

Since a cessation of laying between November 1 and March 1 actually shortens the period of winter production which ends March 1, winter pause birds are certain to lay fewer winter eggs than nonpause birds unless these pause birds are earlier maturing and lay at a higher rate to compensate for the time lost. The mean age at first egg was 190.30 days for the pause group of 693 birds and 194.95 days for the 313 nonpause birds. Mean winter clutch size was 3.21 eggs for the 693 pause birds and 4.02 eggs for the 313 nonpause individuals. These facts show that winter pause actually represents a production loss dependent upon its duration. The coefficient of correlation was calculated between pause duration and winter egg production, giving the following constants.

Number of birds	693
Mean winter production, eggs	78.95
Production standard deviation, eggs	±26.10
Mean pause duration, days	37.11
Pause standard deviation, days	±24.31
Coefficient of correlation	−.5606 ± .0176

Mean winter egg production of the pause group was 78.95 compared with 102.94 eggs for the 313 birds without pause. The actual time loss was 37 days for the pause birds, and in the nonpause group each bird averaged to lay 24 eggs more.

The regression was found to be linear and the correlation coefficient was negative and of considerable magnitude. By squaring the coefficient of correlation it was found that about 31 percent of the variation in winter egg production was due to variation in pause duration. The fact is very obvious, therefore, that winter pause represents a distinct economic loss in winter egg production.

10. Mean Winter Body Weight and Pause Duration

Beginning with the flock hatched in 1934, monthly individual weights of all birds have been taken starting with the day they were housed. The birds were housed at about six months of age and the mean winter body weight represents the average of the monthly weights beginning with the housing weight and concluding with the February weight. It is desirable to know whether body weight affects either the presence or duration of winter pause. The correlation coefficient has been calculated on 322 pause birds hatched in 1934. Body weight has also been recorded on 244 nonpause individuals in the same flock. The following constants were determined:

Number of birds	322
Mean winter weight, pounds	6.11
Weight standard deviation, pounds	±.64
Mean pause duration, days	35.24
Pause standard deviation, days	±22.98
Coefficient of correlation	+.0731±.0374

The mean winter weight for the pause group was 6.11 pounds and for the nonpause group 5.97 pounds. Evidently body weight was not a factor contributing to winter pause because the mean weight was essentially the same for the two groups. The variability in body weight within the pause population cannot be considered high.

Regression of pause duration on body weight was found to be strictly linear. The coefficient of correlation, however, is of insignificant value, indicating that pause duration was independent of winter body weight.

11. Character of Pause Duration

Figure 1 presents the frequency distribution of the pause population with respect to duration of winter pause. The fact should be noted that the 693 birds included make up 68.9 percent of the flocks studied. The graph does not depict a normal frequency distribution, because the modal class is made up of birds with the shortest pauses (between 4 and 13 days). It is probable that these short pauses are not due to the same causes as are the longer pauses. By considering only pauses of seven or more days in length it would be possible to closely approach a normal frequency distribution. It is probable, also, that the classification of birds with respect to the presence or absence of winter pause would be more accurate on the seven-day basis, as Hays (1924) pointed out.

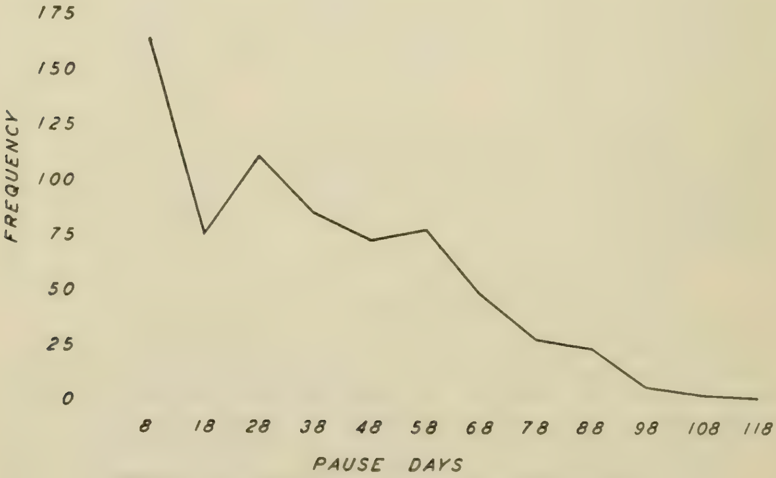


**Figure 1. Frequency Distribution in Pause Duration.
693 Birds — 1933 and 1934.**

12. Laying-House Mortality in Pause and Nonpause Birds

Any relation between the presence or absence of winter pause and mortality in the laying houses is very important to the breeders. In table 2 the mortality rates for the pullet laying year are recorded in the two flocks. These data suggest a somewhat higher mortality rate in the birds with winter pause. There is certainly no evidence from these limited data to indicate that a pause period during the winter will reduce laying-house mortality.

Table 2. — Mortality in Relation to Winter Pause

Year Hatched	Nonpause Birds			Pause Birds		
	Number of Birds Died	Number of Birds Lived	Mortality Percent	Number of Birds Died	Number of Birds Lived	Mortality Percent
1933	20	48	29.41	137	234	36.93
1934	77	168	31.43	122	200	37.89
Total	97	216	30.99	259	434	37.37

13. Hatchability from Pause and Nonpause Birds

Poultrymen generally believe that pullets which exhibit a winter pause and partial molt are more likely to give superior hatches than those laying continuously, particularly when the pullets were hatched early. Bronkhorst and Hall (1935) classified Leghorns as low in hatchability if less than 50 percent of their eggs hatched, and as high if 75 percent or more hatched. They reported that their high-hatching birds averaged to pause 79.3 days and their low-hatching birds 72.8 days, but considered this difference in length of rest period to be of questionable significance. Warren (1934) obtained similar results with Leghorns and Rhode Island Reds. He reported for Leghorns a mean hatchability of 66.37 percent for nonpause birds and 72.48 percent for pause birds; for Rhode Island Reds, 54.34 percent for nonpause birds compared with 66.15 percent for those with winter pause. He did not believe that the higher hatchability in the pause birds was due to the rest from production.

In Table 3 data are presented on pause and nonpause pullets used for breeding for two hatching years. The nonpause birds showed a slightly higher hatchability in both years, which is not in agreement with Warren's observations. In the station flock of Rhode Island Reds, pullets hatched at weekly intervals from March 4 to April 23 and exhibiting no winter pause were at least equal in hatchability to those with pause. There was no evidence to indicate that a period of nonproduction in winter will raise the hatching percentage.

TABLE 3. — HATCHABILITY FROM PAUSE AND NONPAUSE BIRDS

Year	Nonpause Birds		Pause Birds	
	Number of Birds	Percent Hatchability	Number of Birds	Percent Hatchability
1933	13	83.46	71	78.41
1934	35	88.69	56	84.05
Total	48	87.27	127	80.90

Summary

Certain environmental and hereditary characters were studied, to discover what effect they might have on the presence or absence of winter pause and on the duration of winter pause in production-bred Rhode Island Reds.

1. Birds hatched during March showed a somewhat higher incidence of winter pause than those hatched during April. Date of hatching gave a negative correlation with pause duration of $.2366 \pm .0242$.

2. Age at first egg showed no correlation with pause duration.

3. Body weight at first egg was not associated with pause duration.

4. Short intervals between eggs of a clutch during any winter month had a tendency to shorten the winter pause.

5. Large winter clutch size tended to shorten the winter pause.

6. The ability of pullets to lay large numbers of eggs before pausing had a tendency to shorten the winter pause.

7. In general, a significant reduction in pause duration was associated with long periods of previous egg production.

8. Short pauses were likely to be followed by greater egg production than were long pauses. Winter pause cannot, therefore, be considered as a recuperative period to be followed by increased egg production.

9. Winter pause very significantly reduced winter egg production. The mean winter egg record for pause birds was 78.95 and for nonpause birds 102.94. Winter pause birds averaged to lose about 37 days in the winter productive period.

10. Mean body weight from housing up to March 1 was essentially the same in pause and nonpause pullets, and showed no relation to pause duration.

11. Pauses of less than seven days are probably due to different causes than are longer pauses. There is some evidence that pauses of less than seven days are not governed by inherited factors.

12. Laying-house mortality was not reduced by the winter pause.

13. Hatchability was not increased by the presence of winter pause.

References

Bronkhorst, J. J., and G. O. Hall. 1935. Hatchability studies, II. A physical study of eggs from high and low hatching hens. Poultry Sci. 14 (2): 112–115.

Hays, F. A. 1924. Inbreeding the Rhode Island Red fowl with special reference to winter egg production. Amer. Nat. 58: 43–59.

Hays, F. A. 1936. Time interval between eggs in Rhode Island Reds. Jour. Agr. Research (In press).

Hays, F. A., and Ruby Sanborn. 1926. Winter cycle and winter pause in relation to winter and annual egg production. Mass. Agr. Expt. Sta. Tech. Bul. 8.

Warren, D. C. 1934. The influence of some factors on the hatchability of the hen's egg. Kans. Agr. Expt. Sta. Tech. Bul. 37.

PUBLICATION OF THIS DOCUMENT APPROVED BY THE COMMISSION ON ADMINISTRATION AND FINANCE
3m. 3-'36. No. 7292.

VIRGINIA POLYTECHNIC INSTITUTE
AGRICULTURAL BRANCH LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

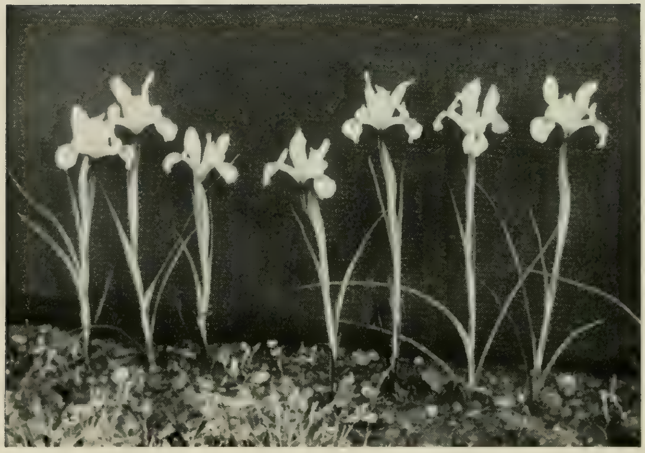
Bulletin No. 330 April 1936

The Bulbous Iris and its Outdoor Culture in Massachusetts

By Frank A. Waugh

Although bulbous irises are easily one of the most beautiful and adaptable groups of flowering plants, the belief that they are not hardy for this latitude has hindered their general introduction. This bulletin presents information about varieties and methods of culture which it is hoped may lead to their more general use in hardy gardens.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.



Dutch Iris, Dirk Dalens, Showing Habit of Growth.

THE BULBOUS IRIS AND ITS OUTDOOR CULTURE IN MASSACHUSETTS

By **Frank A. Waugh**, Professor of Landscape Architecture

The genus Iris includes many species. Some of these are so popular and long-known as to fall into the list of "old-fashioned flowers." Others are rare; some indeed are unknown in garden cultivation.

One group in particular seems to have been sadly overlooked. This is the group of species, hybrids, and varieties commonly called the bulbous irises. Extended experiments with these plants have proved that they have emphatic values for common garden use which have been long and unfortunately missed.

Popular opinion has it that these varieties — usually designated as Spanish, Dutch, and English — are not hardy in the open garden. This limitation is usually placed against the supposedly cold climate of New England, though it is a curious fact that the bulbous irises are not planted any more extensively in the south than in the north. Small plantings several years ago showed that certain varieties, at least, were eligible for use here. This discovery led to further trials, until about ten years ago when more comprehensive tests were begun. Plantings were increased from year to year until the fall of 1933 when a collection of all known varieties available in the American trade was undertaken. To these a few imported bulbs from Holland were added.

Now it will be easily remembered that the winter of 1933–34 was a record-breaker for low temperatures. Thousands of apple trees in this state were killed by freezing. The winter of 1934–35 was hardly less severe. Thus the heaviest plantings of iris bulbs came just in time for the severest possible test. And, since this point of winter hardiness is precisely the one at which gardeners and nurserymen have balked, the test was most opportune.

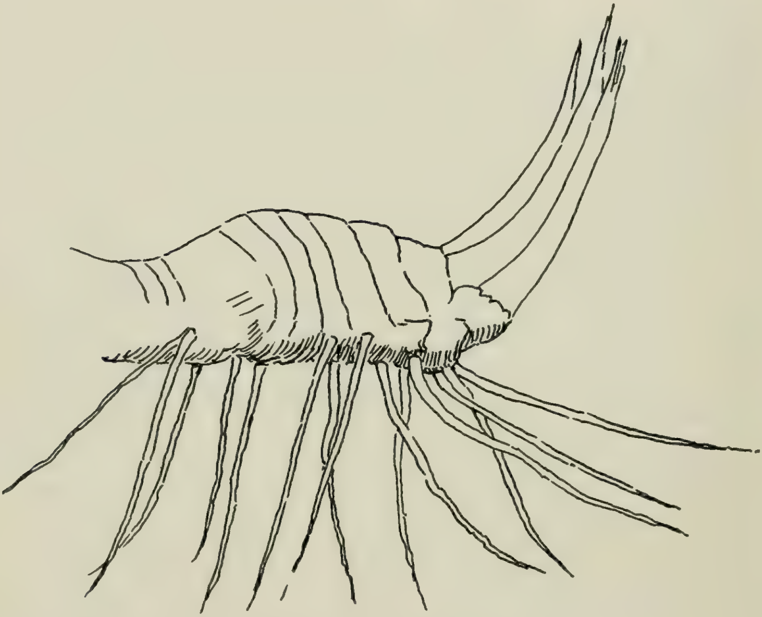
The results were as emphatic as could be asked. During these two winters, with thousands of bulbs in the college gardens, *not one single bulb has been lost by freezing,* so far as could be ascertained. Bulbs are sometimes eaten by rodents, they are subject to other accidents; they sometimes give up this life during the summer; but in growing these irises out of doors, over a period of 30 years, there has never been a single convincing case of loss from winter freezing. So far as can be determined, iris bulbs are quite as winter-hardy as Darwin tulips or tiger lilies.

In short, here is a group of extraordinarily beautiful garden flowers generally considered to be unavailable for common use but which it now appears may be freely planted in any Massachusetts garden wherever desired. And since these are possibly the most beautiful of all the irises (the flowers are often compared to the finest orchids) and since there are no other cultural difficulties to be overcome, it all sounds like good news to New England garden lovers.

Botanical Status

Considerable confusion has existed with reference to the botanical status of the bulbous irises. A brief statement on this head may be of service to gardeners.

The genus Iris is a large one. Bailey's Encyclopedia (Hasselbring in Bailey St. Cyc. Hort. 3:1682. N. Y. 1915) describes 110 species; also a number of botanical varieties. Dykes' outstanding monograph on this genus (Dykes, The Genus Iris, Cambridge, Eng. 1913) lists 139 species with many varieties and hundreds of synonyms. The genus easily divides into several well-marked sections. Garden lovers are familiar, for example, with the German iris, the Siberian iris, and the Japanese iris, and easily recognize the striking differences between these groups.

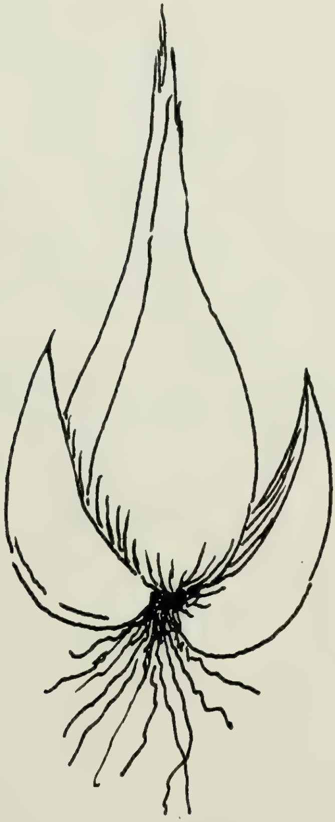


Rhizome of German Iris.

These better-known irises grow from rootstocks or from rhizomes, while the varieties here under discussion grow from bulbs, much like crocus or tulips. All the bulbous irises of special importance to the horticulturist belong to one botanical subgenus called Xiphium, in which group Hasselbring (op. cit.) describes 11 species. Following the classification used by Hasselbring, the botany of the commoner bulbous irises may be summarized as follows:

Spanish Iris, *Iris xiphium*, Linn.: leaves narrow and grasslike, about 1 foot long; flowers in various colors, blues being prominent, always with a yellow blotch on the falls; bulb small, about 1 inch in diameter. Coming into blossom in June; used in forcing; represented in the American trade by varieties like Cajanus, Louise and Blanche Fleur.

English Iris, *Iris xiphioides*, Ehrh.: leaves much larger, broader and more abundant; flowers in various colors, blue predominating, large and very showy, flowering later than the Spanish iris. Here belong Royal Blue, Prince of Wales, Mt. Blanc, and Perle des Jardins.



Bulb of Dutch Iris.

Dutch Iris. In most of the catalogs will be found a list of varieties under the head of Dutch Iris. These seem to be hybrids originating in Holland, produced by crossing *I. tingitana*, Bois., with *I. xiphium*, *I. boissieri*, Henriq, and possibly with other species. The effects of these hybridizations, however, have not been very marked, and the Dutch irises resemble the Spanish varieties rather closely. The foliage seems to be broader and more abundant and the plants generally more vigorous. The flowers appear early, usually a few days before the Spanish iris. Some of the best forcing and garden varieties are found in this doubtful group, e.g., Hart Nibbrig, Imperator, Golden Bronze, and Poggenbeek. Dykes (op. cit. p. 214) shows a plate of *Iris xiphium* var. *praecox* and suggests (p. 215) that this name might be appropriately applied to the Dutch iris.

Iris tingitana, Bois., should be mentioned here since, besides being the parent of possible hybrids in the foregoing group, certain commercial varieties are sometimes referred to this species by the nurserymen. The tingitana iris are generally supposed to be less hardy than the Spanish and English varieties, but this weakness has not been observable in the experimental plots here. The distinctions between this and the former groups are mainly technical, having little horticultural significance.

Mention might also be made of the fact that some other species of bulbous iris are coming into the American trade. The one to attract most recent notice is *I. reticulata*, Bieb., a very small and very early flowering species. This is a prize for collectors of interesting plants, particularly suited to the rock garden.

Experiments at M. S. C.

About thirty years ago bulbous irises, mostly from the Spanish group, were introduced in the gardens at Massachusetts State College. They proved hardy and satisfactory. About ten years ago the culture of the English varieties was begun. These seemed so very attractive and results were so greatly different from common report, that a somewhat comprehensive test was undertaken of all varieties of bulbous irises commercially available. Bulbs were secured from growers in Washington and Oregon, some were bought through New York dealers, a few were ordered from Holland. A review of these varieties follows herewith.

Variety Notes

Explanation of Table

1. Variety: This is usually the catalog name as given by the dealer. Incorrect or doubtful names have been thrown out. Synonyms have not been determined.
2. Class: S — Spanish; D — Dutch; E — English; T — Tingitana.
3. Time of Bloom: Average date of beginning; all dates are for Amherst, Mass., and are in June. The asterisk is used to indicate those varieties which have been grown here only in the greenhouse.
4. Height in inches.
5. Flowers, general description: Fine distinctions of color are not attempted.
6. Standards: Notes relate mainly to color.
7. Falls: Same as for standards.
8. Crests: Size and color indicated.
9. Eye: Always yellow; notes relate mainly to size.
10. Remarks: As required.

VARIETY NOTES

Variety	Class	Time of Bloom (June)	Height Inches	Flowers, General	Standards	Falls	Crests	Eye	Remarks
A. Bloemaard	D	8	17	Dark delft	Blue	Delft	Blue	Narrow	Good
Abraham Storck	D	12	18	Dark delft	Dark blue	Dark blue	Dark blue	Large	Flowers large and fine
Adrian Backer	D	8	16	Violet	Dark violet	Violet	Violet	Narrow	Good
A. L. Koster	D	11	16	White	White	Cream	White	Large	Weak and uneven
Anton Mauve	D	6	17	Violet	Violet	Violet	Dark violet	Large	Good
Arie Scheffer	D	7	16	Purple	Purple	Dark delft	Purple	Narrow	
Beauty	?	25	22	White	White, purple lines	White	White	Medium	
Blanche Fleur	S	18	23	White	White	White	White	Large	Strong, good
Bleu Amable	E	25	19	Pale violet	Flecked	Flecked	Pale violet	Medium	Good
Bleu Celeste	D	13	18	Navy	Dark blue	Blue veined	Blue	Medium	Good
Bleu Celeste	E	27	22	White	Cream	Cream flecked	Pale blue	Narrow	Strong
Blue Horizon	D	12	17	Blue	Delft	Pale blue	Medium blue	Large	Uneven
Blue Monarch	D	*	21	Blue violet	Violet	Large, blue	Blue	Medium	
Blue Perfection	D	12	16	Blue	Smoky	Delft	Medium blue	Large	Weak
Bronze	S	14	14	Bronze	Purple	Green bronze	Bronze purple	Medium	Probably same as Bronze Queen
Bronze Queen	S	14	20	Bronze	Purple	Bronze	Bronze	Large	Fine
Cajanus	S	21	26	Yellow	Pale yellow	Yellow	Pale	Dark	One of the best

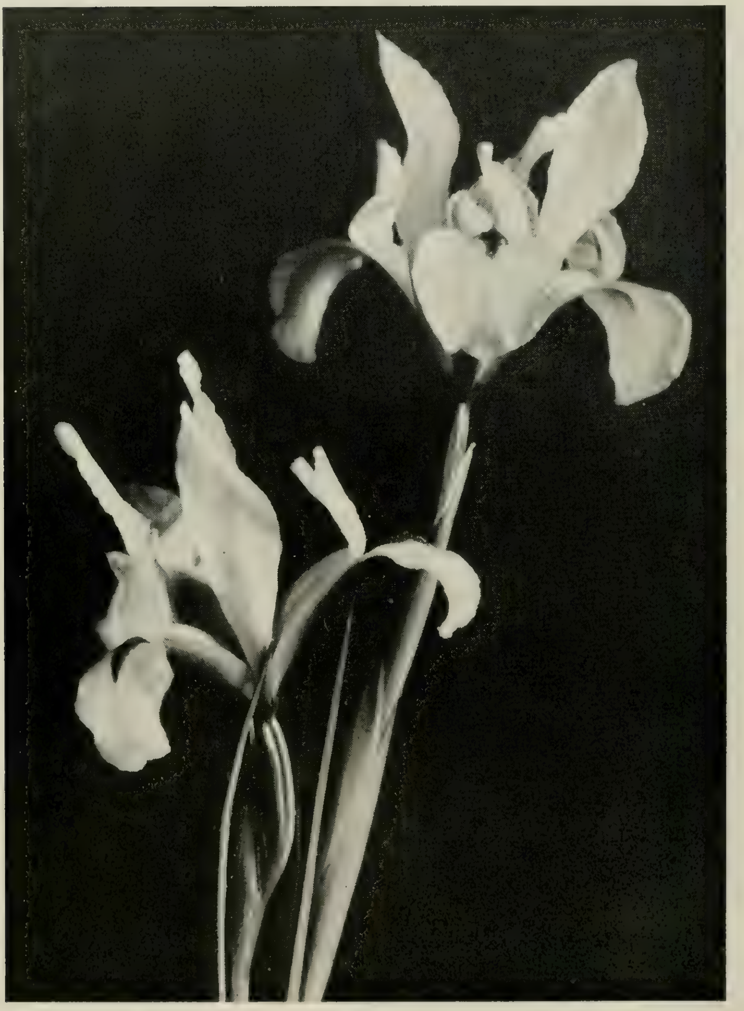
Variety Notes

Variety	Class	Time of Bloom (June)	Height Inches	Flowers, General	Standards	Falls	Crests	Eye	Remarks
Canary Yellow	S	19	22	Cream	White	Cream	Cream	Large	Good
Cattleya	E	22	19	Pale blue	Blue flecked	Pale blue	Pale blue	Small	
Celestial	D	12	19	Blue	Navy	Delft	Medium blue	Large	Promising
Chrysolora	S	19	17	Yellow	Paler yellow	Yellow	Pale yellow	Dark	Good
Clara Butt	E	22	18	Pale blue	Blue flecked	Pale blue	Pale blue	Narrow	
Count of Nassau	S	20	21	Blue	Navy	Delft	Blue	Large	Good
D. Haring	D	9	22	White	White	White	White	Small	Good
De la Martine	E	25	12	Pale violet	Pale violet	Pale violet	Pale violet	Small	
Dirk Dalens	D	15	18	Pale blue	Pale blue	Blue veined	Pale blue	Medium	Very good
Duke of Clarence	E	25	20	Pale blue	Blue	Powder blue	Blue	Medium	Good
Early Snow	D	7	20	White	White	White	White	Small	Good
E. B. Garnier	D	12	21	Blue	Navy	Blue veined	Pale blue	Medium	Good
Elias Voet	D	12	?	Blue	Navy	Dark blue	Blue	Medium	
Elrow Banner?	D	*	17	Yellow	Pale yellow	Lemon yellow	Lemon yellow	Small	
Emperor	E	22	18	Blue	Pale blue	Navy	Dark blue	Small	Promising
Franz Decker	D	7	21	White	White	White	White	Small	
Flora	S	12	21	White	Pale blue	Cream	Pale blue	Small	
Floris Verster	D?	7	13	Dark blue	Dark blue	Dark blue	Blue	Large	Weak
Floris van Schooten	D	7	20	Yellow	Yellow	Yellow	Pale yellow	Dark	Weak

Gerrit van Hees	D	13	19	Violet	Violet	Violet	Violet	Medium	
Golden Bronze	D	17	14	Bronze	Bronze purple	Bronze	Bronze purple	Large	Weak but pretty
Golden Glory	D	15	20	Yellow	Yellow	Yellow	Yellow	Very small	Good
Golden Sunshine	S	*	22	Yellow	Pale yellow	Lemon yellow	Yellow	Small	
Golden Wonder	D	14	18	Yellow	Yellow	Yellow	Yellow	Small	Same as Golden Glory?
Grand Lilas	E	24	20	Pale lilac	Pale flecked	Pale flecked	Pale	Small	Strong, good
Grand Vainquer	E	28	21	Pale blue	Pale flecked	Pale	Pale	Small	Strong, good
Hart Nibbrig	D	20	14	Blue	Violet blue	Delft	Violet blue	Small	Good
H. G. Pot	D	7	13	Pale blue	Pale blue	Pale blue	Very pale		Small and weak
Hobbema	D	9	21	Very pale	Pale lilac	Cream	Pale lilac		Good
Huchtenburg	D	9	15	Odd	Pale blue	Yellow	Pale yellow	Dark	Odd and interesting
Imperator	D	16	20	Blue	Dark blue	Dark blue	Dark blue	Large	Good
Imperator	D	*	23	Blue violet	Violet	Delft blue	Delft	Medium	Strong
Indian Chief	D	12	19	Bronze	Bronze	Bronze	Bronze	Small	Striking color
Jac Adrian Nathan	D	10	16	Delft	Dark delft	Delft	Dark	Large	
Jacob de Wit	D	13	20	Violet	Violet	Violet	Violet	Large	Good
King Edward	E	24	19	Purple	Dark purple	Dark purple	Dark purple	Small	
King of the Blues	E	20	20	Blue	Dark blue	Delft	Pale blue	Small	Very good
King of the Yellows	S	17	21	Yellow	Yellow	Yellow	Yellow	Dark	Poor
La Reconnaissance	S	17	12	Bronze	Bronze purple	Bronze and yellow	Smoky	Small	
Leornado di Vinci	D	*	18	White and yellow	White	Pale yellow	White		Very pretty
Louise Sport	S	17	15	Very pale blue	Pale blue	Pale blue	Pale blue	Small	

Variety	Class	Time of Bloom (June)	Height Inches	Flowers, General	Standards	Falls	Crests	Eye	Remarks
Lucinda	E	25	22	White	White	White	White shaded	Small	Good
Mauve Queen	?	22	15	Pale	Pale lavender	White and lavender	Pale lavender	Small	
Mont Blanc	E	30	24	White	White	White	White	Small	One of the whitest
Nic Willing	D	7	20	White	White	White	White	Small	Weak
Nimrod	E	28	22	Dark blue	Navy	Navy flecked	Dark blue	Large	
P. C. Verbeek	D	11	20	Yellow	Pale yellow	Dark yellow	Yellow	Medium	
P. de Moulyn	D	7	19	Blue	Dark blue	Navy	Navy	Large	Good
Perle des Jardins	E	25	20	Pale blue	Pale blue	Pale	Darker	Medium	
Poggenbeek	D	7	18	Blue	Navy	Blue	Medium blue	Medium	
Prince Henry	S	12	?	Bronze	Bronze lilac	Bronze	Bronze lilac	Small	Striking
Prince Mauritz	E	20	17	Purple	Purple	Purple mottled	Purple	Small	Strong
Prince of Wales	E	24	18	Dark blue	Navy	Navy veined	Navy		White throat, one of the finest
Princess Dagmar	E	27	16	White	White flecked	White flecked	Pale violet	Small	
Purple King	E	27	22	Purple	Purple	Purple	Purple	Small	
Queen Alexandra	E	27	16	Blue	Violet over white	Blue veined	Pale	Small	Odd
Queen Emma	S	*	27	Yellow	Lemon yellow	Sulfur yellow	Medium yellow	Small	Strong
Rembrandt	D	8	18	Blue	Purple blue	Dark blue veined	Dark blue	Large	Good

Royal Blue	E	27	25	Dark blue	Dark blue	Dark blue flecked	Dark blue		Strong, fine
S. de Vlieger	D	12	14	Pale blue	Delft	Pale delft	Delft	Small	Uneven
S. Rambout	D	5	12	Blue	Navy	Delft	Delft	Small	
Sunset	E	27	23	Lavender	Lavender	Lavender flecked	Lavender	Small	Strong
Supreme	T								Did not blossom
Surprise	E	24	17	Dark blue	Dark navy	Very dark blue	Dark navy	Small	Good, strong
S. van Ruysdael	D	9	13	Blue	Blue	Lilac	Dark blue	Small	Odd and attractive
The First	T	4	22	Blue	Blue	Delft	Blue	Small	Strong and good
Therese van der Schwartze	D	9	17	White	Pale delft	Cream	Pale delft	Small	
Th. Wyck	D	5	10	Blue	Navy	Delft	Light navy	Small	Weak
Thunderbolt	S?	14	17	Bronze	Smoky	Bronze	Bronze purple	Large	Same as Goldcup
Tricolor	E	20	17	Pale	Lavender mottled	White	Pale delft	Small	Strong, good
Van der Helst	D	5	16	Yellow	Pale yellow	Dark yellow	Pale yellow	Small	Showy, fine
Van Everdingen	D	5	17	Yellow	Cream	Yellow	Pale yellow	Dark	Like foregoing, but inferior
Wedgewood	T	5	23	Pale blue	Blue	Pale delft	Blue	Large	Earliest, sturdy, tall, fine
White Excelsior	D	7	15	White	White	White	White	Small	Good
W. de Nooy	D	7	17	Yellow	Pale yellow	Lemon yellow	Pale yellow	Dark	
W. Zuiderveld	D	7	18	Blue	Delft	Delft	Delft	Small	
Yellow Queen	D	8	18	Yellow	Yellow	Yellow	Yellow	Small	Good



Dutch Iris, Dirk Dalens.

English Iris

Culture of Bulbous Iris

Briefly stated, the culture in the open of bulbous iris is the same as of the common hardy tulips (Darwins, breeders, and cottage varieties). The bulbs are received from the dealers early in the fall, about October 1. They should be planted immediately in well-drained soil and in a sunny location. Bulbs should be set 4—5 inches deep and 4 inches to 1 foot apart. They will usually be set in rows, but planting in compact beds is perfectly satisfactory. The bulbs will soon begin to grow and most varieties will send up green spearlike shoots to a height of 4 or 5 inches before freezing. This development is apt to cause anxiety to the novice, as it appears to be a sure promise of winterkilling. However, this is the habit of the plants and no harm seems to follow.

It has been the usual, though not invariable, practice to give some winter protection. Sometimes a straw mulch has been used; but the commoner method, and the one recommended is to wait till the ground is frozen and then to place a few evergreen boughs over the beds. These evergreens will hold the snow and the snow will provide all necessary insulation.

In the books, a dressing of lime has often been recommended for iris bulbs. Though the soil here is normally acid, and though liming has been tried in several instances, no results have been demonstrable.

By July 1, the flowers will be past. Once more the bulbs may be treated like tulips. During the month of July they may be lifted, dried off, the young bulbels separated, and the whole replanted in late September. Or if it is more convenient the bulbs may be left entirely alone where they stand. Some varieties will maintain their place in the garden for several years without any further bother; but most varieties tend to run out under this laissez-faire system.

Since the bulbous irises are especially superb for cutting, and since cutting must always take heavy toll of the foliage, it can hardly be expected that good flowers will be produced by the same bulbs year after year. It will be necessary on this account to keep bringing in young and vigorous bulbs from the natural increase or else to buy fresh bulbs annually. This latter practice is more expensive, but it gives better results.

The present bulletin is concerned primarily with the garden culture of bulbous iris, but the fact should at least be mentioned that a principal portion of the bulb crop is used by florists for forcing in their greenhouses. The cut flowers of the most sumptuous beauty are offered in the florists' stores during the midwinter months. The Department of Floriculture at Massachusetts State College has regularly forced small quantities of iris each winter for many years past and testifies to their great desirability in this role.

Making a Beginning

On the basis of the experience here set forth it would seem proper to recommend the bulbous irises (meaning varieties of the so-called Dutch, Spanish, English, and Tingitana groups) for general cultivation by amateur gardeners in Massachusetts. They seem likely to give abundant satisfaction in home gardens wherever the common hardy flowers are grown. In cultural requirements they are most closely allied to tulips and crocus; anyone who succeeds with these common bulbs will hardly fail with bulbous iris.

Formerly the bulbs imported from Holland — a few varieties only — were available at absurdly low prices. In later years the United States quarantines have practically excluded the Holland bulbs, and under the impetus of this exclusion the production of iris bulbs has slowly developed in the United States, particularly in the Pacific Northwest. These American bulbs are much more expensive than were the same varieties imported from Holland 25 years ago, but it should be promptly added that the quality is vastly superior. The retail prices of northwestern-grown iris bulbs are at present substantially equal to the prices of tulip bulbs, say 50c to $2 a dozen. Standard varieties usually rate $1 a dozen or a little less. These bulbs may be ordered from most good seedsmen, florists, or nurserymen or direct from the Washington and Oregon growers. Orders should be placed early, preferably not later than August, and bulbs should be planted promptly on delivery.

The following varieties are suggested for a beginning:

DUTCH: Rembrandt, Imperator, Poggenbeek (much like Imperator), Hart Nibbrig, D. Haring, Golden Glory, Indian Chief (odd and interesting), White Excelsior.

SPANISH: Cajanus, Bronze Queen, Blanche Fleur, Count of Nassau.

ENGLISH: Duke of Clarence, Grand Lilas, Grand Vainquer, King of the Blues, Mont Blanc, Prince of Wales, Royal Blue, Tricolor. (Don't fail to include some English varieties in every experimental planting.)

TINGITANA: The First, Wedgewood.

If the first trials must be on a very small scale, the following varieties may be chosen as representatives:

DUTCH: Hart Nibbrig.

SPANISH: Cajanus, or Bronze Queen.

ENGLISH: Prince of Wales, or Royal Blue.

TINGITANA: The First, or Wedgewood.

Good amateur gardeners, of course, have always the possibility of increasing their stock of bulbs from year to year from their own propagations, but too much reliance should not be placed on this at first.

PUBLICATION OF THIS DOCUMENT APPROVED BY THE COMMISSION ON ADMINISTRATION AND FINANCE
7500-4'36. No. 7550.

AGRICULTURAL [illegible] LIBRARY
BLACKSBURG, VIRGINIA
331

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 331 April, 1936

The Development of the Testes and Scrotum of the Ram, Bull and Boar

By Ralph W. Phillips and Frederick N. Andrews

A knowledge of the normal course of development of the testes and scrotum is necessary as a basis for the management and feeding of young developing males. This bulletin reports studies of certain phases of the subject on which definite information has been lacking.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE DEVELOPMENT OF THE TESTES AND SCROTUM OF RAM, BULL, AND BOAR

By Ralph W. Phillips, Instructor in Animal Husbandry, and Frederick N. Andrews, Graduate Assistant in Animal Husbandry

INTRODUCTION

A thorough understanding of the rate of development of the testes, the age at which spermatozoa are first produced, and the factors which affect the development of the testes and scrotum is essential as a basis for recommendations for the management and feeding of young males. Little definite information is available concerning these problems, and the experiments herein reported were designed to help supply this lack.

Research in recent years has shown that the testes of most mammals must be maintained at a temperature considerably lower than that of the body cavity if they are to develop and function normally. The temperature in the scrotum is considerably lower than the body cavity temperature and is maintained at a fairly constant level by the activity of the tunica dartos, a muscular tissue which lies just under the skin of the scrotum. This muscle reacts very quickly to any temperature change, acting very much like a thermostat, drawing the testes close to the body in cold weather, allowing them to be at a maximum distance from the body in hot weather, and at intermediate temperatures constantly lengthening and shortening as the temperature in the scrotum varies.[1] Since the tunica dartos muscle is essential to normal functioning of the testes, a knowledge of how this muscle develops and the relationship between its development and that of the testes becomes of interest and value.

Studies of the following phases of these problems are reported here:

(1) The normal development of the testes of the ram, bull, and boar.
(2) The effect of low nutrition upon the development of testes in the boar.
(3) The normal development of the tunica dartos in the ram, bull, and boar.
(4) Factors which affect or control the development of the tunica dartos.

DEVELOPMENT OF THE TESTES

Ram

A series of fourteen rams (Southdowns and Shropshires) was castrated at ages varying from 21 to 189 days. Blocks of tissue were taken, fixed, sectioned, and stained for histological study.

At 21 days of age the seminiferous tubules contained only a single, irregular row of cells on the basement membranes, the lumina being filled with an opaque mass and an occasional free cell. At 42 days the row of cells had become more regular and the material filling the lumina showed signs of breaking up. Little change occurred from this time until 63 days when a few primary spermatocytes had appeared. At 84 days an increase in primary spermatocytes was noted, a further increase was noted at 105 days, and at 126 days some secondary spermatocytes were present and the lumina were clear in most of the tubules. Spermatozoa had appeared at 147 days of age.

---

[1] Phillips, R. W., and McKenzie, F. W. The thermo-regulatory function and mechanism of the scrotum. Mo. Agr. Expt. Sta. Research Bul. 217. 1934.

Measurements were made of the diameters of the seminiferous tubules, showing the increase in the size of tubules that takes place during development. Representative measurements are given in Table 1.

TABLE 1. — DIAMETERS OF SEMINIFEROUS TUBULES IN THE TESTES OF THE RAM AT VARIOUS AGES.

Age at Castration (Days)	Diameter of Tubules (Micra)
21	36.5
42	43.5
63	54.5
84	64.7
105	82.1
126	119.7
147	163.4

Rapid development of the germinal epithelium in this series began at about 84 days of age and spermatozoa first appeared at 147 days. Photomicrographs of representative sections are shown in Figures 1 to 4.

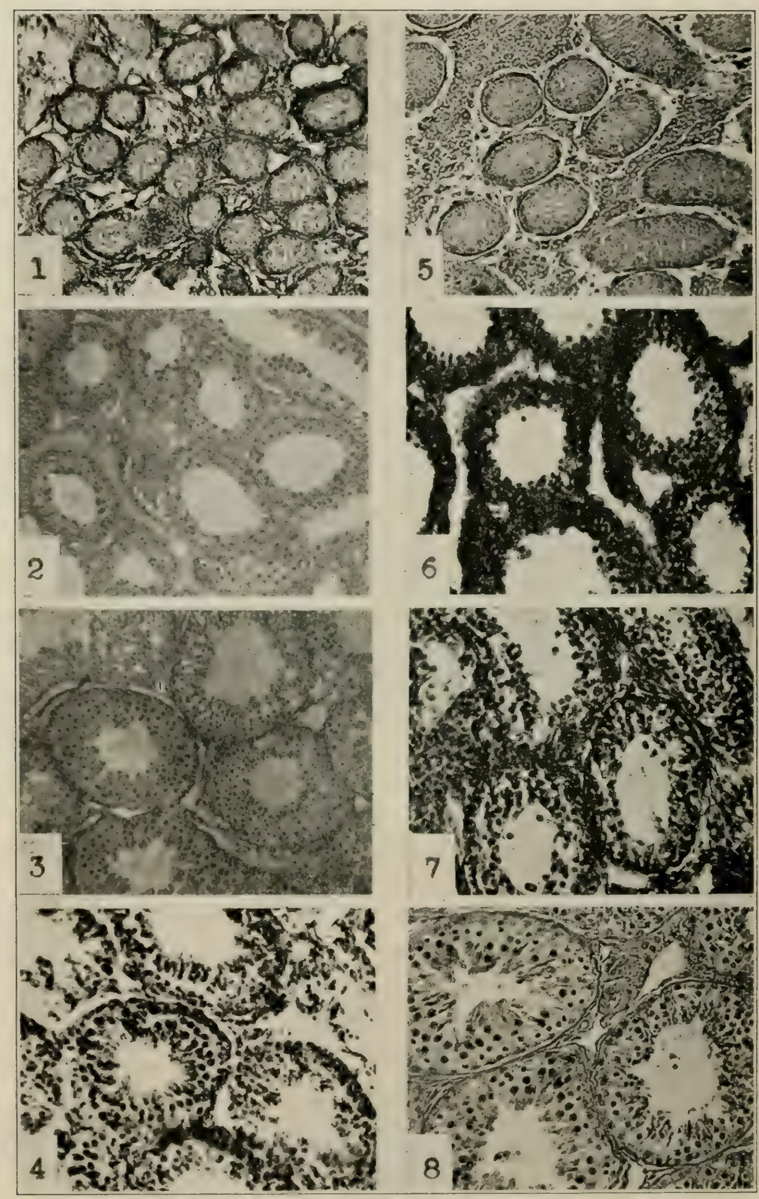
Bull

A study was made of nine bulls representing four breeds and ranging from 63 to 450 days of age. Blocks of testes were taken at the time of castration and prepared for histological examination. Measurements were taken of the tubules, and the average diameter at each of the nine stages is given in Table 2.

TABLE 2. — DIAMETERS OF SEMINIFEROUS TUBULES IN THE TESTES OF THE BULL AT VARIOUS AGES

Age at Castration (Days)	Diameter of Tubules (Micra)	Breed
63	70.3	Guernsey
65	58.0	Holstein
88	60.6	Shorthorn
104	72.8	Shorthorn
142	81.9	Hereford
181	116.1	Hereford
224	148.9	Hereford
261	154.1	Hereford
450	217.3	Shorthorn

At 63 days the seminiferous tubules contained only a loosely arranged row of spermatogonia and an occasional primary spermatocyte. The lumina were filled with an opaque mass of material. Little change was observed in the next three stages, except for an increase in primary spermatocytes at 104 days. Rapid development of the epithelium began after the 104-day stage. At 142 days primary spermatocytes were present in all tubules, and at 181 days secondary spermatocytes had appeared in all tubules. Spermatozoa were present in many tubules at 224 and 261 days and in all tubules at 450 days. After 142 days the material filling the lumina gradually disappeared, leaving a rather large lumen with epithelial cells arranged in a compact layer near the basement membrane. This continued until the last stage examined (450 days), when the epithelial cells occupied most of the space in the tubules.



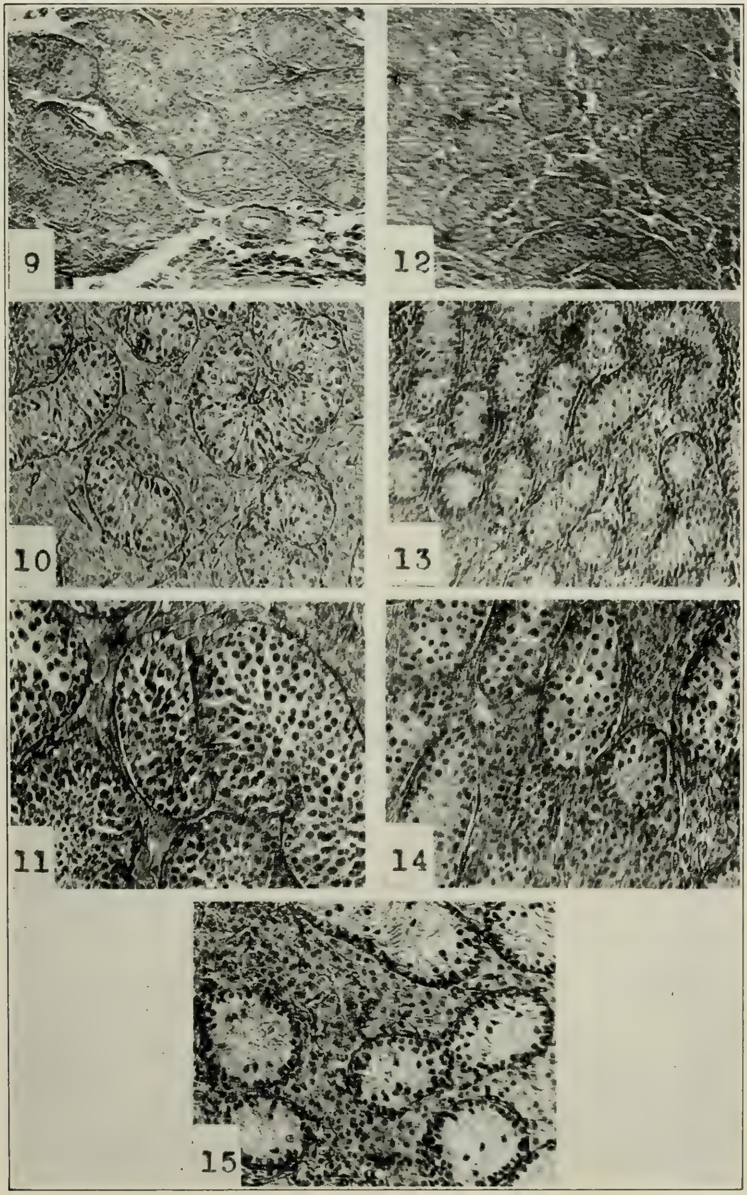
Photomicrographs of Sections of the Testes at Various Ages during Development. (130x)

The Ram

Figure 1 — 42 days
Figure 2 — 126 days
Figure 3 — 147 days
Figure 4 — 168 days

The Bull

Figure 5 — 63 days
Figure 6 — 224 days
Figure 7 — 261 days
Figure 8 — 450 days



Photomicrographs of Sections of the Testes of the Boar at Various Ages during Development, Showing the Effect of Low Nutrition. (130x)

High-Nutrition Group (Normal)	**Low-Nutrition Group**
Figure 9 — 84 days	**Figure 12 — 84 days**
Figure 10 — 105 days	**Figure 13 — 105 days**
Figure 11 — 147 days	**Figure 14 — 147 days**
	Figure 15 — 168 days

The rapid development of the germinal epithelium, then, began at about 142 days in this series, and spermatozoa first appeared at 224 days. Photomicrographs of representative sections taken from this series are shown in Figures 5 to 8.

Boar

Eight boars (Chester Whites and Berkshires) were castrated at ages ranging from 12 to 147 days. Blocks of testes were taken and prepared for histological examination. The ages of all the boars and the diameters of the tubules at each age are given in Table 3.

TABLE 3. — DIAMETERS OF SEMINIFEROUS TUBULES IN THE TESTES OF THE BOAR AT VARIOUS AGES

Age of Castration (Days)	Diameter of Tubules (Micra)
12	51.6
21	50.9
42	56.7
61	62.5
84	59.3
105	83.8
126	139.9
147	165.7

Little development of the germinal epithelium was observed until after 84 days of age. The spermatogonia were arranged in a loose layer on the basement membranes at 12 days and the remainder of each tubule was filled with an opaque mass. In the succeeding stages the spermatogonia became arranged in a compact and orderly fashion around the basement membrane and primary spermatocytes gradually appeared, so that a few were present in all tubules at 84 days of age. In the 105-day stage secondary spermatocytes had appeared in some tubules, and at 126 days the epithelium appeared completely organized except for spermatozoa. Spermatozoa were present in some tubules at 147 days.

It would seem from this series of animals that the testes of the boar develop slowly up to about 84 days of age, and that after this age a more rapid development sets in, with spermatozoa first being produced at about 147 days. Photomicrographs of sections from three of the boars in this series are shown in Figures 9 to 11.

Boar — Low Nutrition Series

Five boar pigs were fed from weaning age (6 weeks) on a very low plane of nutrition. These pigs were castrated at from 84 to 168 days of age. As shown in Table 4, the gains made in body weight were low when compared with the gains of the normal group described above, some of which were used for controls.

TABLE 4. — GAINS MADE BY BOAR PIGS ON HIGH AND LOW PLANES OF NUTRITION

Age at Castration (Days)	Gain from Weaning to Time of Castration (Pounds)	
	High Nutrition	Low Nutrition
84	19	14
105	70	16
126	95	36
147	140	56
168	–	71

At the time of castration measurements were taken of the volume of the testes (with epididymis removed) and of the diameter of the tubules. These figures are given in Table 5 and show that the low plane of nutrition resulted in a marked slowing up of the growth of the testes in total size as well as in the diameter of the seminiferous tubules.

TABLE 5. — EFFECT OF LOW NUTRITION ON VOLUME OF TESTES AND DIAMETER OF SEMINIFEROUS TUBULES

Age at Castration (Days)	Volume of Testes (c.c.) (Both Testes)		Diameter of Tubules (Micra)	
	High Nutrition	Low Nutrition	High Nutrition	Low Nutrition
84	12	10	59.3	55.4
105	107	13	83.8	58.6
126	220	83	139.9	122.5
147	300	82	165.7	99.3
168	—	68	—	96.7

The development of the germinal epithelium was also retarded by low nutrition when compared with litter-mate controls, with one exception. The exception was the 126-day stage which showed a fully developed epithelium with numerous spermatozoa. The other ages examined showed little development of the epithelium. At 84 and 105 days only spermatogonia and a few spermatocytes were present. At 147 days secondary spermatocytes had appeared; but at 168 days, the oldest stage examined, only spermatogonia and a few primary spermatocytes were present.

Photomicrographs of sections from four of the boars on a low plane of nutrition are shown in Figures 12 to 15, where they may be compared with controls shown in Figures 9 to 11.

DEVELOPMENT OF THE TUNICA DARTOS

Materials for the study of the tunica dartos muscle were obtained from all the animals from which testes were obtained. The development of the tunica dartos was studied in two ways. At the time of castration two strips of tissue were taken along the vertical axis of the scrotal wall. One was fixed and prepared for histological examination and the other was mounted in aerated Ringer's solution, attached to a muscle lever, and subjected to temperature changes. Starting at about 37°C. the temperature was gradually lowered to 20°, held there for five minutes, and then gradually returned to approximately 37°. The reactions of the strips to these temperature changes were recorded on a kymograph.

Ram

Fourteen ram lambs varying in age from 21 to 189 days were used. Records of the reaction of isolated strips of the tunica dartos muscle to temperature changes were obtained as described above. Measurements were then made to determine the altitude of the contractions and the temperature to which it was necessary to lower the fluid surrounding the strip of muscle before it began to contract. These records for each animal are given in Table 6.

TABLE 6. — THE DEVELOPMENT OF SENSITIVITY TO TEMPERATURE CHANGES IN THE TUNICA DARTOS MUSCLE OF THE RAM.

Age at Castration (Days)	Altitude of Contraction (mm.)	Temperature at which Contraction Began (°C.)
21	8	31
42	11	32
48	4	30
52	9	34
61	2.5	30
63	6	36
64	23	35
70	6	36
84	37	36
105	23.5	37
126	28	37
147	38	35
168	41	36
189	39	36

It may be noted that up to 64 days only small contractions occurred, but that all strips from rams 64 days of age or over (with one exception, 70 days) showed a marked reaction to the temperature changes to which they were subjected. The temperatures at which the muscles began to contract ranged from 30° to 34°C. up to 63 days, but in all the older stages contraction began at from 35° to 37°C., indicating that the muscle becomes more sensitive to temperature changes as the animal matures. Four representative records are shown in Figure 16.

The histological changes which occur as the tunica dartos develops consist chiefly of an increase in the relative and total amount of smooth muscle fibers and a decrease in the relative amount of connective tissue. Most of the strands of smooth muscle follow the long axis of the scrotum, but some on the inner surface run at oblique and right angles. The strands anastomose frequently and in the earlier stages are interspersed with large amounts of connective tissue. As the animal grows older the muscle becomes thicker, the strands of smooth muscle become larger and tend to join together to make larger strands, and relatively less connective tissue is present between the strands. Photomicrographs of representative sections are shown in Figures 18 to 20.

It is interesting to note that the age at which the tunica dartos became markedly sensitive to temperatures changes (63 to 84 days) was approximately the same as the age (84 days) at which rapid development of the germinal epithelium was first observed.

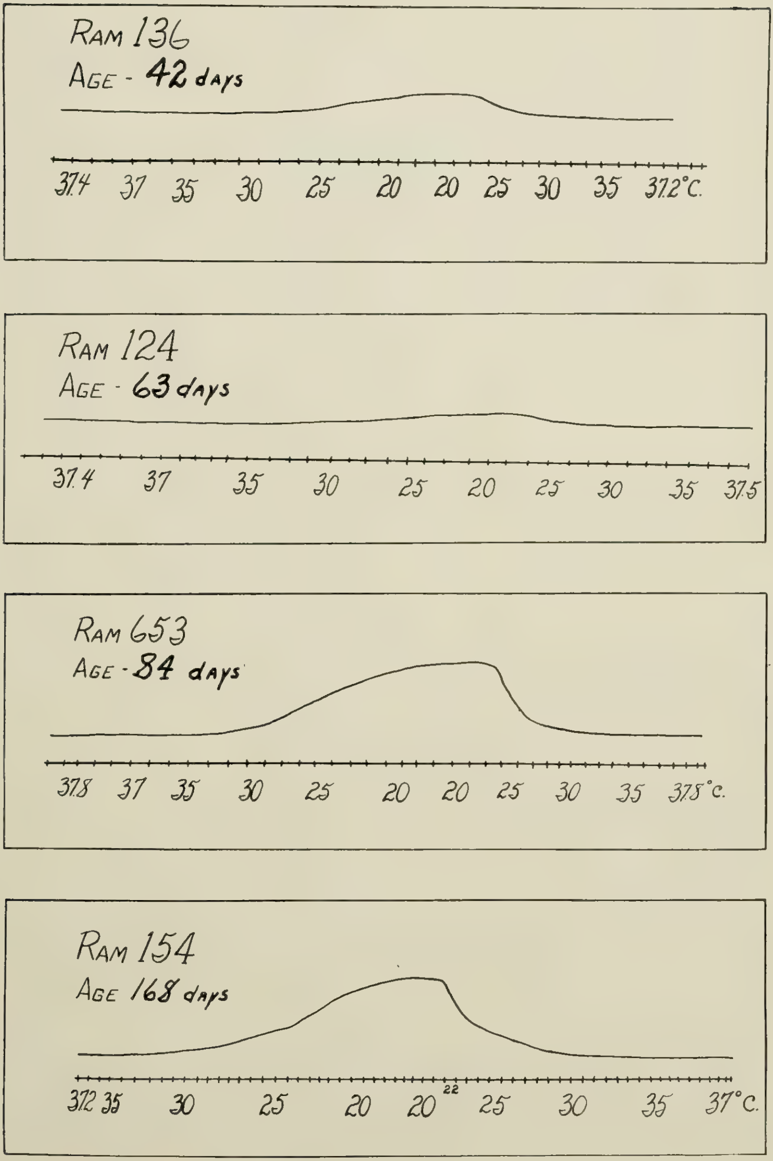


Figure 16. Kymograph Records Showing the Development of Sensitivity to Temperature Changes in the Tunica Dartos Muscle of the Ram.

Records were taken on isolated muscle strips. Time is in one-minute intervals on the base line, and temperatures are recorded in °C.

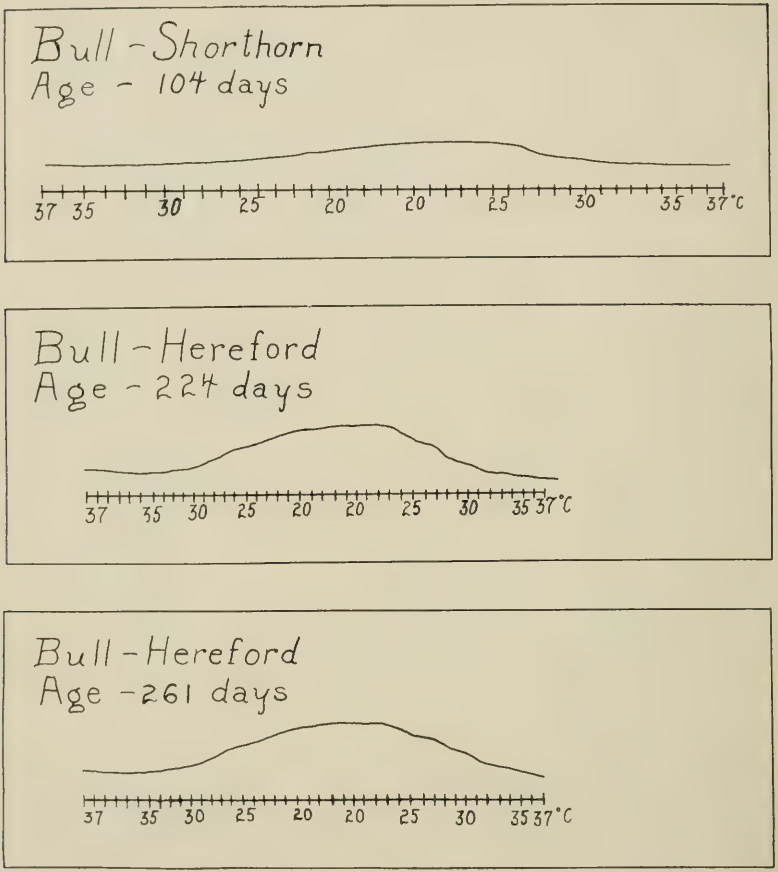


Figure 17. Kymograph Records Showing the Development of Sensitivity to Temperature Changes in the Tunica Dartos Muscle of the Bull.

Records were taken on isolated muscle strips. Time is in one-minute intervals on the base line, and temperatures are recorded in °C.

Bull

The physiological and histological development of the tunica dartos in the bull was very similar to that in the ram. The series showed more variation, probably because of the variety of breeds represented. The age, breed, and altitude of contraction recorded for each animal are given in Table 7. The temperature at which contraction began varied so little from 36°C. that these figures are omitted.

The large contraction observed at 88 days does not fit in with the results on the other younger animals. Rapid development of the germinal epithelium of the testes was first observed at 142 days, and at this time the tunica dartos in this animal did not show any marked sensitivity to temperature changes. However, the tunica dartos showed a marked reaction to temperature changes at 224 and 261 days of age, the first two stages in which spermatozoa were observed in the seminiferous tubules. Three records from the series are shown in Figure 17.

TABLE 7. — THE DEVELOPMENT OF SENSITIVITY TO TEMPERATURE CHANGES IN THE TUNICA DARTOS OF THE BULL.

Age at Castration (Days)	Altitude of Contraction (mm.)	Breed
63	2.0	Guernsey
65	.5	Holstein
88	27.5	Shorthorn
104	11.0	Shorthorn
142	7.0	Hereford
181	1.0	Hereford
224	23.0	Hereford
261	24.5	Hereford

The histological development of the tunica dartos muscle is a gradual process similar to that in the ram. The smooth muscle strands gradually become more prominent as the animal becomes older, but the older stages have considerably more connective tissue between the muscle strands than is found in the ram. Representative stages are shown in Figures 21 to 23.

Boar

The development of the tunica dartos in the boar closely parallels that in the ram and bull. Therefore, detailed data are not presented. Of the nine stages studied, ranging from 12 to 147 days of age, only the three oldest (105, 126, and 147 days) gave a marked reaction to temperature changes. These last three stages were also the ones in which rapid development of the germinal epithelium took place. Some representative records of the reactions to temperature changes are shown in Figure 27.

The histological changes are similar to those described for the ram. Representative sections are shown in Figures 24 to 26.

FACTORS AFFECTING THE DEVELOPMENT OF THE TUNICA DARTOS MUSCLE

The fact that the tunica dartos becomes sensitive to temperature changes at about the time when rapid development of the germinal epithelium begins in the ram and boar, and by the time spermatozoa are produced in the bull, would seem to indicate a relationship between the development of the testes and that of the tunica dartos muscle. Results submitted below support this theory.

Castration

Seven of the rams used in studying normal development of the scrotum were retained and strips of the tunica dartos obtained at various intervals after castration. These strips were subjected to temperature changes and the reaction of the strips recorded on a kymograph. The altitude of contractions and the temperatures at which contractions began are given in Table 8, along with records of these rams at the time of castration.

TABLE 8. — THE EFFECT OF CASTRATION UPON THE DEVELOPMENT AND MAINTENANCE OF TEMPERATURE SENSITIVITY IN THE TUNICA DARTOS MUSCLE OF THE RAM.

Animal	At Castration			After Castration		
	Age (Days)	Altitude of Contraction (mm.)	Temperature at which Contraction Began (°C.)	Age (Days)	Altitude of Contraction (mm.)	Temperature at which Contraction Began (°C.)
A	42	11	32	84	9	32
				238	1	30
B	63	6	36	126	5.5	34
				231	1	28
C	84	37	36	231	20.5	36
D	105	23.5	37	231	22.5	36
E	126	28	37	231	6	33
F	147	38	35	231	1	28
G	189	39	36	231	8	34

An examination of the figures reveals two interesting points: (a) If a ram was castrated before the tunica dartos developed a marked sensitivity to temperature changes, this sensitivity did not develop later; and (b) if a ram was castrated after the tunica dartos had developed a sensitivity to temperature changes, this sensitivity tended to be lost. Both of these facts indicate that the tunica dartos depends upon the presence of the testes for normal development and maintenance of its temperature-regulating function.

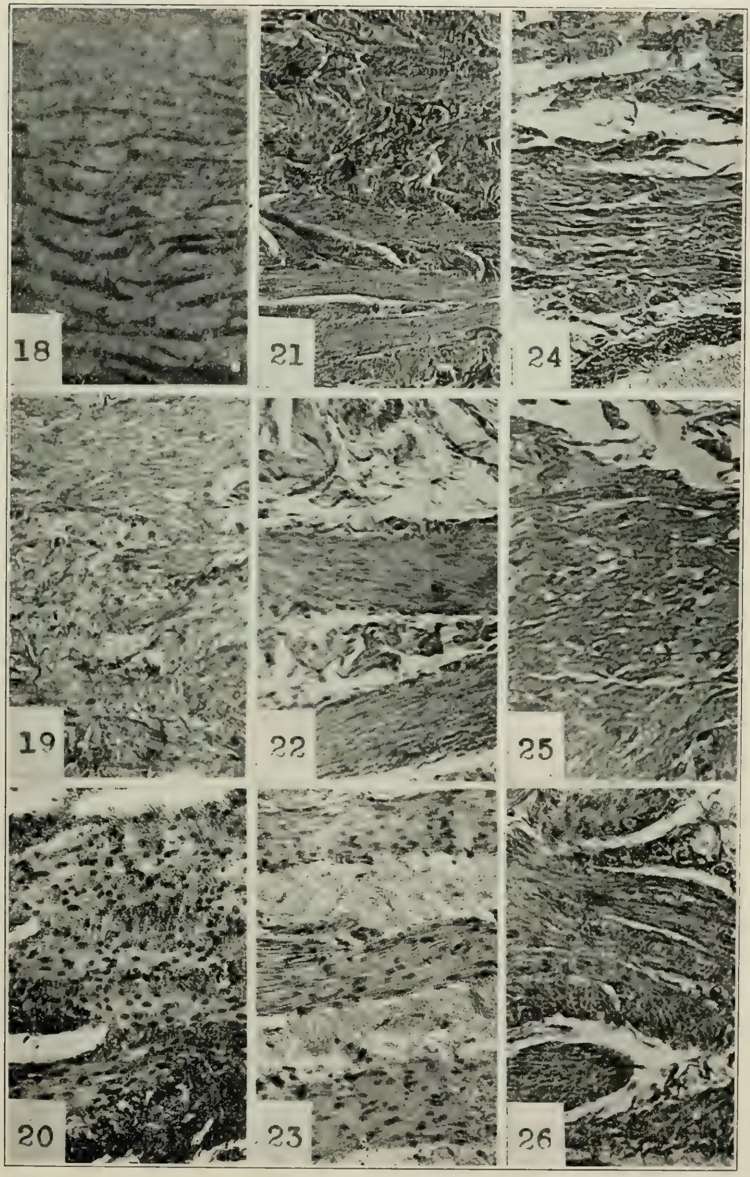
Testicular Hormone Injections

Seven ram lambs were injected with testicular hormone ("Hombreol"), the dosage varying from 20 to 100 cock units. At the end of the injection periods (7 to 18 days) these lambs ranged in age from 41 to 56 days. Strips of the tunica dartos were taken and subjected to temperature changes as has been described earlier in this bulletin. When compared to normal rams four of these showed some precocious development of the tunica dartos muscle. These rams ranged in age from 41 to 54 days when the strip of tissue was excised and had received from 60 to 100 cock units of "Hombreol" over a 10 to 13 day period. The amount of activity was not equal to that observed in rams of 84 days of age and over, but some precocious development was obvious.

Weight of the Testes

The above observations indicate that the testicular hormone, or one fraction of it, is concerned with the development of the tunica dartos. It seemed possible that the weight of the testes might also have some effect on the development of this muscle. To check this, two ram lambs were castrated and the testes replaced by steel balls. The tunica dartos of one of these rams had not developed a reaction to temperature changes at the time of castration (28 days) and did not develop it later. The second ram had developed some reaction when castrated at 62 days but lost this sensitivity following the replacement of the testes by steel balls.

Results with these two animals indicate that weight of the testes is not a factor in the development of the tunica dartos.



Photomicrographs Showing Histological Changes during the Development of the Tunica Dartos Muscle. (130x).

(Note the increase in size of the strands of smooth muscle.)

The Ram

Figure 18 — At birth
Figure 19 — 84 days
Figure 20 — 189 days

The Bull

Figure 21 — 63 days
Figure 22 — 104 days
Figure 23 — 261 days

The Boar

Figure 24 — 61 days
Figure 25 — 84 days
Figure 26 — 147 days

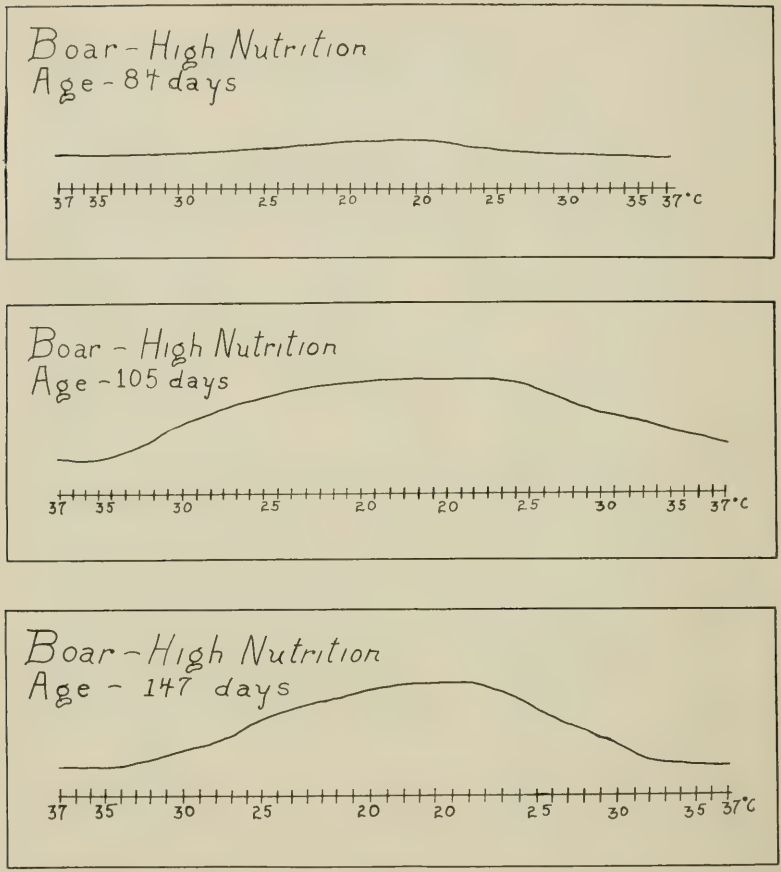


Figure 27. Kymograph Records Showing the Development of Sensitivity to Temperature Changes in the Tunica Dartos Muscle of the Boar

(High Nutrition — Normal.)

Records were taken on isolated muscle strips. Time is in one-minute intervals on the base line, and temperatures are recorded in °C.

Low Nutrition

In an earlier section a series of boar pigs that were fed on a low plane of nutrition is described. Records were made of the reactions of strips of the tunica dartos from these boars at the time of castration. The altitudes of contractions observed in strips of tissue from these animals are given in Table 9, along with figures from litter-mate controls fed on a high plane of nutrition. Three of the records of the low-nutrition group are shown in Figure 28.

The figures show that the tunica dartos had not developed as much in the low-nutrition group at 105 days and over as it had in the high-nutrition group. The development of the testes was also retarded, as already noted. Since the tunica dartos seems to depend upon the testicular hormone for its development,

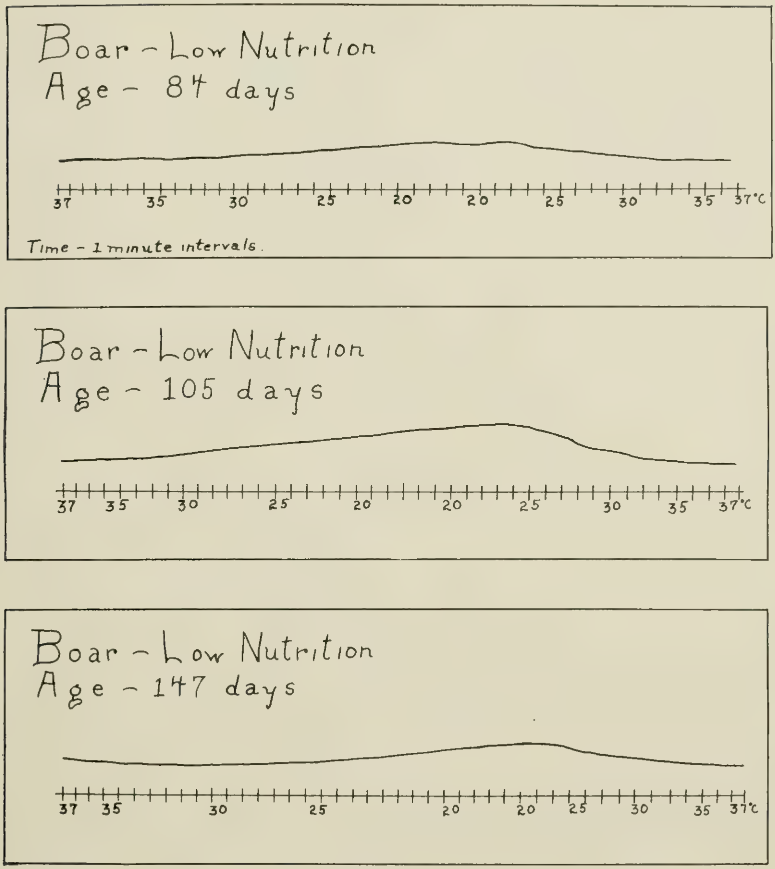


Figure 28. **Kymograph Records Showing the Effect of Low Nutrition upon Development of Sensitivity to Temperature Changes in the Tunica Dartos Muscle of the Boar. Compare with controls in Figure 27.**

it is possible that the retarding of testicular development was responsible for the slowing up of the development of the tunica dartos.

Table 9. — The Effect of Low Nutrition upon Development of the Tunica Dartos Muscle of the Boar

Age at Castration (Days)	Altitude of Contraction (mm.)	
	High Nutrition	Low Nutrition
84	6.5	8.0
105	41.0	18.0
126	68.5	37.0
147	41.5	11.2
168		18.5

One other point is of interest here. The tunica dartos of the 126-day-old boar in the low-nutrition group showed the most marked reaction to temperature changes. This boar also showed marked development of the germinal epithelium as compared to that of the other animals on low nutrition. There is an indication here that the testicular hormone or the fraction of it responsible for the development of the tunica dartos may be elaborated by the germinal epithelium. It will be remembered, also, that in the normal animals the first marked activity of the tunica dartos and that of the germinal epithelium are closely associated.

SUMMARY

The work reported in this bulletin was concerned with the development of the testes and of the tunica dartos muscle in the scrotum of the ram, the boar, and the bull. The experimental results may be summarized briefly as follows:

1. Marked development of the germinal epithelium was first noted at 84 days of age in the ram, 142 days in the bull, and 84 days in the boar.
2. Spermatozoa first appeared in the normal series at 147 days in the ram, 224 days in the bull and 147 in the boar.
3. With boars, a low plane of nutrition resulted in a considerable retardation of development of the testes as measured by testicular volume, diameter of the seminiferous tubules, and development of the germinal epithelium (with one notable exception).
4. The tunica dartos muscle first showed a marked reaction to temperature changes at from 63 to 84 days in the ram and at 105 days in the boar. Results with the bull were somewhat variable.
5. Studies of the effect of castration and injections of testicular hormone indicate that, in the ram, the tunica dartos is dependent upon a testicular hormone for the development and maintenance of its reactivity to temperature changes.
6. Weight of the testes does not appear to be a factor in the development of the temperature-regulating mechanism of the scrotum.
7. Low nutrition in the boar resulted in a retarding of the development of the tunica dartos muscle. It seems possible that this is an indirect effect resulting from a retarding of development of the testes.
8. The evidence presented seems to indicate that the tunica dartos muscle is dependent upon a testicular hormone for the development and maintenance of its sensitivity to temperature changes.

Publication of this Document Approved by Commission on Administration and Finance
3m — 5-'36. No. 7772.

140
332

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 332 June 1936

The Cranberry Industry In Massachusetts

By C. D. Stevens, H. J. Franklin, C. I. Gunness,
and V. C. Peterson

Cranberry growing is an important source of agricultural income in Massachusetts. In recent years it has been exceeded only by dairying, poultry raising, and vegetable growing. This study brings together both the historical and the latest available statistical information regarding the development of this important industry.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE CRANBERRY INDUSTRY IN MASSACHUSETTS[1]

By C. D. Stevens, H. J. Franklin, C. I. Gunness and V. C. Peterson[2]

INTRODUCTION

An average of about 555,000 barrels of cranberries was produced annually in the United States during the last twenty years (1915–1934 inclusive). Massachusetts produced an average of 356,000 barrels or about 64 percent of the entire crop during this period. The rest of the crop came mainly from New Jersey and Wisconsin and a small quantity from Washington and Oregon.

The cranberry which is native to the northeastern United States was first cultivated at North Dennis, Massachusetts, between 1810 and 1820; but it was not until about 1850 that enough experience was accumulated to grow this crop commercially. Cranberries are (1935) and have been for many years the leading export crop of the State and are shipped to all parts of the United States and Canada. The total income from cranberry production in Massachusetts in recent years has been exceeded only by that of dairying, poultry raising, and vegetable growing. The total value of the cranberry crop averaged $4,056,000 from 1925 to 1934, this average being greater than that of any other Massachusetts crop except hay. In 1934 the cranberry crop was valued at $3,277,000, a total considerably in excess of the combined value of the commercial apple and potato crops of Massachusetts. The value of the crop in 1934 was about 12 percent greater than that of the commercial apple crop of all New England.

As cranberries are a perishable product with a rather brief marketing season, it is important that those who grow and market cranberries should have reliable estimates of the size of the crop if it is to be sold to the best advantage. Such estimates are essential to the development of sound advertising and price policies. To provide an adequate basis for estimating the crop, special surveys of acreage, management, and production, and of disposal of the fruit must be made from time to time, for it has been found that census data and assessors' reports do not furnish adequate information. The last previous general survey of the industry was made in 1924.

As a basis for the detailed survey, lists of owners were secured from the assessors' records of the various towns, on file in the Massachusetts Department of Corporations and Taxation. The enumerators then visited owners or managers individually and secured the information required. This has been carefully analyzed and the results are presented here.

---

[1] The survey on which a large part of this study is based was organized in March 1934, as a part of the National Recovery Research Project (ERA S-G-5 and CWA 6604-5) under the direction of the Massachusetts Agricultural Experiment Station in cooperation with the New England Crop Reporting Service, which is a joint agency of the United States Department of Agriculture, and the Massachusetts Department of Agriculture. The field work was begun in March 1934, under the supervision of V. A. Sanders who remained with the project only a short time, and was completed in August 1934, under the direction of V. C. Peterson, Junior Statistician, assisted by E. A. Richmond.

[2] This project was initiated and brought to completion by C. D. Stevens, Federal Statistician in charge of the New England Crop Reporting Service, Division of Crop and Livestock Estimates, Bureau of Agricultural Economics, United States Department of Agriculture, and Dr. H. J. Franklin, in charge of the Cranberry Station of the Massachusetts Agricultural Experiment Station. The analysis of data on pumping equipment is the contribution of C. I. Gunness, Professor of Agricultural Engineering, Massachusetts State College. The assistance of Asst. Research Professor R. L. Mighell in securing the financing of this project as a part of the Emergency Relief Administration and Civil Works Administration programs for employment is hereby acknowledged.

H. P. Plunkett, in charge of personnel, secured an excellent force of about thirty enumerators and clerks to carry on the details of the project.

This report also compares the results of the 1924 and 1934 surveys, important changes in the industry being noted. It includes fairly complete historical data of the Massachusetts cranberry acreage and of the production in each of the important cranberry-growing regions of the country. It gives a record of cranberry prices since 1863, together with a study of their relation since 1900 to business conditions, cranberry production, and other factors. A record of Cape Cod cranberry frosts since 1912 kept by the Cranberry Station at East Wareham is included. The statistical material is presented rather fully in tabular form and is freely illustrated with charts.

CRANBERRY BOG ACREAGE

Cranberry bogs were first planted in Barnstable County, and here the cranberry industry had its most rapid early development. The Massachusetts State census report for 1885 (see Table 1) gives the bog acreage of Barnstable County as 2,408 acres, of Plymouth County as 1,347 acres, and of Worcester County as 77 acres. No acreage is given in this report for any other county, though cranberry crops are reported for every county in the State except Suffolk. In the State census for 1895, however, cranberry acreage is reported for every county except Hampshire and Suffolk, and the State census for 1905 gives bog acreage for all the counties except Suffolk.

Table 1 — Massachusetts Cranberry Bog Acreage

County	1885*	1895*	1905*	1915†	1924‡	1934§
Barnstable	2,408	3,255	4,677	4,433	4,331	3,500
Berkshire		21	4			
Bristol		371	291	471	422	464
Dukes		70	64	154	46	62
Essex		365	157	10	10	14
Franklin		37	29			
Hampden		68	25			
Hampshire			48			
Middlesex		641	778	71	115	128
Nantucket		34	51	291	330	304
Norfolk		269	289	60	55	74
Plymouth	1,347	3,766	6,240	8,628	8,582	9,091
Worcester	77	475	374	5	5	7
STATE TOTAL		9,372	13,027	14,123	13,896	13,644

* Massachusetts State Census report † Assessors' reports
‡ Assessors' reports carefully rechecked from other sources
§ Personal canvass of all cranberry bog owners or managers

From 1885 to 1895, Plymouth County added nearly three times as many acres to its total as did Barnstable County. This gave Plymouth County a lead of over 500 acres, which has since been maintained and increased. These two counties easily lead all others in the cranberry industry. In 1895, in the order of their relative importance, were Middlesex, Worcester, Bristol, Essex, and Norfolk Counties. Their combined acreage, however, was only about a third of that of Barnstable and Plymouth Counties. The acreages of the remaining five counties that reported ranged from 70 for Dukes County to 20 for Berkshire, a total of 230 acres.

By 1905, Barnstable County had 4,677 acres, an increase of more than 1,400 acres during the ten-year period. This was the time of the greatest expansion of the industry in this county. From 1905 to 1924, this acreage decreased moderately but steadily. From 1924 to 1934, it declined nearly a fifth and is now only about 250 acres greater than it was in 1895.

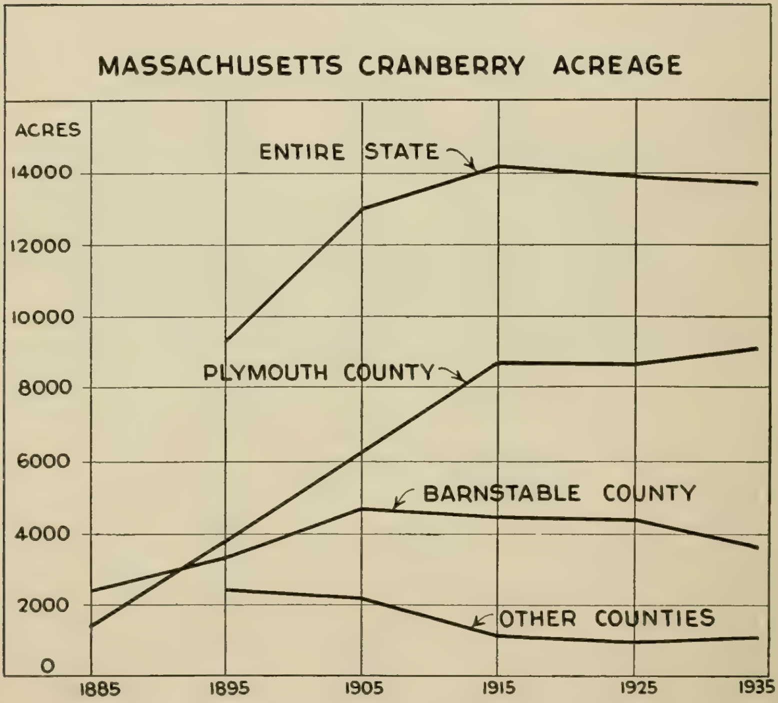


Figure 1.

Plymouth County increased its acreage from 1895 to 1905 by nearly two-thirds, and again by more than a third from 1905 to 1915. The acreage remained practically unchanged from 1915 to 1924, but increased nearly 6 percent from 1924 to 1934 when it was nearly two and a half times as great as in 1895.

Of the other counties, only Bristol and Nantucket had greater acreages in 1934 than they had in 1895. Bristol had increased its acreage about a fourth. Nantucket, with only 34 acres in 1895, had 304 in 1934. Dukes County decreased its acreage during this period from 70 to 62; Essex, from 365 to 14; Middlesex, from 641 to 128 Norfolk, from 269 to 74 and Worcester, from 475 to 7. Berkshire, Franklin, Hampden, and Hampshire dropped out of the picture. The acreage of all the counties except Barnstable and Plymouth, taken as a unit, shrunk somewhat over 200 acres from 1895 to 1905, was further reduced about one-half from 1905 to 1915, and has since remained nearly stationary.

The State totals show the net result of the changes in acreage in the different counties in the various periods. This total was 9,372 acres in 1895 and had increased to 13,027 acres by 1905, but only about a thousand acres were added from 1905 to 1915. This marked the high point of acreage expansion for the State. From 1915 to 1934 the acreage declined slightly, the net change being less than 500 acres.

To summarize: Barnstable County reached its maximum acreage in 1905 and then declined steadily until now, the decline being most rapid during the last ten years. The trend of acreage in Plymouth County, on the other hand, has been steadily upward, reaching a record high of 9,091 acres in 1934. The other counties, as a unit, have followed a downward trend and in 1934 had less than one-half of their peak acreage of 1895. The acreage of the State increased continuously till 1915. Since then there has been a small but steady decrease. Figure 1 shows the trend of Massachusetts cranberry acreage since 1885. The distribution of bog acreage in 1934 by towns is shown in Figure 2.

In 1895, Barnstable County had 34.7 percent of the total cranberry acreage of the State. By 1905 this had increased to 35.9 percent, but it was down to 31.4 in 1915, 31.2 in 1924, and 25.7 percent in 1934. Plymouth County had 40.2 percent of the total acreage in 1895, and this percentage increased substantially in each period thereafter, except the period ending in 1924 when the increase was only 0.7 percent. It had 66.6 percent of the total acreage in 1934. The other counties had 25.1 percent of the total acreage in 1895, but only 16.2 in 1905, 7.5 in 1915, and about the same since then.

These figures might suggest that the industry in this State has stood still, or even retrograded, since 1916. This is far from the case as will be seen later, but its more recent progress has been along other lines than acreage expansion.

POTENTIAL CRANBERRY ACREAGE IN MASSACHUSETTS

Cranberries are grown on peat or muck land. Such soil is an accumulation of organic vegetable matter in varying states of decomposition mixed with mineral material brought in by winds and overflowing water. It ranges from a few inches to many feet in depth and is dark colored. The present developed cranberry area of 13,644 acres in the State is less than 12 percent of the land classified as muck soil in the soil surveys of Barnstable, Plymouth, Norfolk, and Bristol Counties.[3] The areas of bog lands producing cranberries in these counties, and of lands classified as muck by the soil surveys, are as follows:

County	*Muck Land* *Acres*	*Cranberry Bogs* *Acres*
Barnstable	3,200	3,500
Bristol	24,000	464
Norfolk	25,216	74
Plymouth	67,968	9,091

In Barnstable County the acreage of bogs is greater than that of muck lands. Cranberries are being grown there on 300 acres or more of soil not of the best bog type. A considerable increase in the cranberry acreage in Barnstable

---

[3] Soil Survey of Plymouth County, Massachusetts. Bureau of Soils, United States Department of Agriculture, December 12, 1912.

Soil Survey of Norfolk, Bristol, and Barnstable Counties, Massachusetts. Massachusetts Department of Agriculture and Bureau of Soils, United States Department of Agriculture, 1924.

County is, therefore, unlikely for nearly all the available bog land is already developed. The extent of unused muck land in Plymouth, Norfolk, and Bristol Counties shows that there is much room for expansion as far as available soil is concerned; but flooding facilities, sand supplies, and drainage possibilities are as important as the matter of soil. Most of the good cranberry-bog sites in Plymouth County are already taken, but excellent unused locations are scattered as far west as the Connecticut Valley and north to the foothills of the White Mountains. Such sites seem to be especially abundant in Essex and Middlesex Counties. There is, therefore, abundant room in Massachusetts for such further development of the cranberry industry as the growth of population or a wider use of cranberries may promote.

A further increase in production may also come from increased yields per acre as knowledge of cranberry culture progresses.

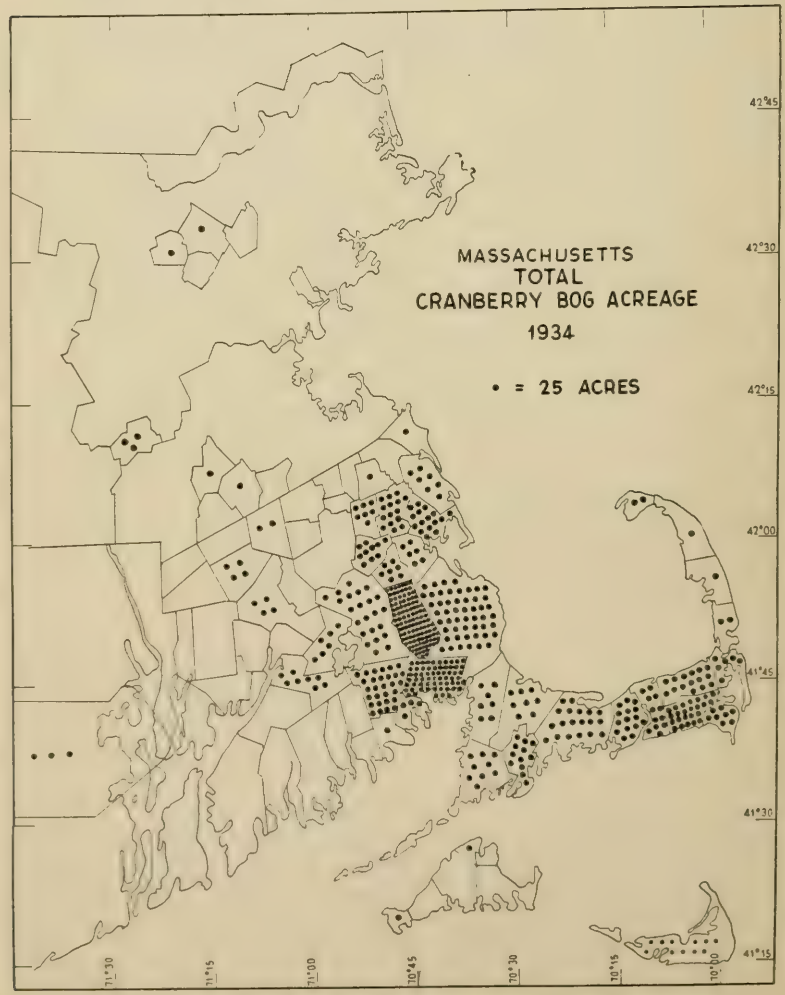

MASSACHUSETTS
TOTAL
CRANBERRY BOG ACREAGE
1934
• = 25 ACRES
42°45
42°30
42°15
42°00
41°45
41°30
41°15
71°30
71°15
71°00
70°45
70°30
70°15
70°00

Figure 2.

TABLE 2. — CRANBERRY BOG HOLDINGS BY COUNTIES AND SIZE GROUPS

Acres	Barnstable		Bristol		Dukes		Essex		Middlesex		Nantucket		Norfolk		Plymouth		Worcester		Total*		Percent of change
	1924	1934	1924	1934	1924	1934	1924	1934	1924	1934	1924	1934	1924	1934	1924	1934	1924	1934	1924	1934	
Less than 1	420	126	0	1	3	1	0	0	0	0	0	1	0	0	77	45	0	0	500	174	- 65.2
1 less than 2	346	144	9	7	3	4	0	1	2	1	0	1	0	0	129	87	0	0	489	245	- 49.9
2 less than 3	176	103	1	1	0	2	0	0	4	1	1	0	1	0	102	68	0	1	285	176	- 38.2
3 less than 4	95	57	3	4	3	4	0	0	0	1	1	3	0	1	81	62	0	0	183	132	- 27.0
4 less than 5	59	49	1	2	1	0	0	0	1	0	0	1	1	1	54	58	0	0	117	111	- 5.1
5 less than 10	130	98	5	6	1	3	0	0	5	1	0	0	3	3	125	113	1	1	270	225	- 16.7
10 less than 15	40	32	0	1	2	0	1	1	3	1	0	0	0	1	62	45	0	0	108	81	- 25.0
15 less than 20	13	17	1	1	0	0	0	0	0	1	1	0	2	2	30	28	0	0	47	49	+ 4.3
20 less than 25	15	9	2	2	0	1	0	0	1	0	0	1	0	0	21	25	0	0	39	38	- 2.6
25 less than 50	17	15	1	3	0	0	0	0	0	2	0	0	0	0	48	34	0	0	66	54	- 18.2
50 less than 100	2	1	2	3	0	0	0	0	0	0	0	0	0	0	27	18	0	0	31	22	- 29.0
100 less than 200	0	3	1	0	0	0	0	0	0	0	1	0	0	0	7	9	0	0	9	12	+ 33.3
200 or over	0	1	0	0	0	0	0	0	0	0	1	1	0	0	3	5	0	0	4	7	+ 75.0
TOTAL	1,313	655	26	31	13	15	1	2	16	8	5	8	7	8	766	597	1	2	2,148	1,326	- 38.3
Average Acres per holder	3.3	5.3	16.2	15.0	3.5	4.1	10.0	7.0	7.2	16.0	66.0	38.0	7.8	9.3	11.2	15.2	5.0	3.5	6.5	10.3	+ 58.5

* Grand Total for 1934 listed above 1,326
Duplication due to growers having bogs in more than one county 13

Actual number of growers in Massachusetts 1,313

SIZE OF CRANBERRY-BOG HOLDINGS

The cultivated Massachusetts bogs range in size from several rods to 235 acres. One of the latter size on Nantucket is the largest As a rule, bogs of 20 acres or less are more profitable than larger ones if they have satisfactory flowage facilities. Some bogs that are a unit in formation are divided into several parcels as to ownership and operation. Table 2 shows the number of individual bog holdings of different sizes in each of the nine Massachusetts counties in which cranberries were grown in 1924 and 1934. The information concerning the holdings in 1924 was secured from the tax records of the various towns and may be regarded as reliable for a general picture of the relative importance of holdings of different sizes in the counties. There were 2,147 bog holdings in the State in 1924 and only 1,313 in 1934, a decrease of 38.8 percent. The average size of all the holdings was 6.5 acres in 1924 and 10.3 acres in 1934, an increase of 58.5 percent. In 1934, 45 percent of the holdings contained less than 3 acres of land and over 80 percent were of less than 10 acres. The 95 holdings of 25 or more acres in 1934 comprised over 58 percent of the entire cranberry acreage of the State, while the 595 holdings of less than 3 acres made up less than 6 percent of the total.

All this indicates that the ownership of a large part of the bog acreage is concentrated in relatively few hands and that the tendency in this direction is continuing.

FLOWAGE

The first classification of cranberry-bog acreage by types of flowage protection was that made in the survey of 1924 (see Table 3). The report of that survey[4] states that "Cranberry bogs are classified as dry bogs, bogs having winter flowage, bogs having winter flowage and one spring flowage, bogs having winter flowage and two spring flowages, and bogs having full flowage protection." This classification was continued in the 1934 survey.

As the name indicates, a dry bog is one not flooded at any season of the year. A bog having winter flowage is one covered with water during the winter. The water may be flowed on by pumping or by gravity from a reservoir, pond, or stream, or may be supplied by rains and snows. In Barnstable County, most of the bogs with winter flowage depend on precipitation for their water supply. Bogs with winter flowage and one or two spring flowages not only have protection against winterkilling, but also have some protection against spring frosts. Bogs with full flowage protection can be flooded at any time, water being available to cover the bog in winter, to protect the new growth from the frosts of spring and the berries from fall frosts, and to control insect infestations.

Table 3 shows that from 1924 to 1934 dry-bog acreage in the State was reduced more than a half and acreage with winter flowage almost a third. Bog acreage with winter and one spring flowage, on the other hand, more than doubled; and that with winter and two spring flowages increased more than five and a half times. Full-flowage bog also increased. Cranberry growers have made outstanding progress in improving flowage facilities during the last ten years.

The distribution by towns of the acreage with full flowage protection in 1934 is shown on the map in Figure 3. Table 16 (in the appendix) gives the

---

[4] Cranberry Acreage and Production in Massachusetts, by the New England Crop Reporting Service and the Massachusetts Department of Agriculture, 1925.

TABLE 3. — CLASSIFICATION OF CRANBERRY BOG ACREAGE IN MASSACHUSETTS ACCORDING TO FLOWAGE PROTECTION 1924* AND 1934

County	Dry Bog		Winter Flowage only		Winter and one Spring Flowage		Winter and two Spring Flowages		Full Flowage		Total Acres	
	1924	1934	1924	1934	1924	1934	1924	1934	1924	1934	1924	1934
Barnstable	927	330	2,066	1,395	101	575	22	117	1,069	1,083	*4,331	3,500
Bristol	29	2	55	79	4	15		8	334	360	422	464
Dukes	14	12	19	38	10	12			3		46	62
Essex			10	2						12	10	14
Middlesex	10	1	32	13			8		65	114	115	128
Nantucket		8	188	31	15	15		225	75	25	*330	304
Norfolk			35			26		15	20	33	55	74
Plymouth	540	364	2,404	1,784	725	1,109	190	863	4,723	4,971	8,582	9,091
Worcester									5	7	5	7
STATE TOTAL	1,520	717	4,809	3,342	855	1,752	220	1,228	6,294	6,605	*13,896	13,644

*In 1924, Barnstable County had 146 acres and Nantucket had 52 acres of bog not classified but included in the State and County totals.

Massachusetts cranberry acreage with different flowage facilities by towns.

The percentage changes shown in Table 4 indicate clearly the improvement that has taken place in flowage facilities on Massachusetts cranberry bogs from 1924 to 1934.

Barnstable County made a relatively greater improvement in its flowage facilities from 1924 to 1934 than did Plymouth County; but the great lead held by Plymouth County in this respect prior to 1924, together with its very substantial improvement since then, gives it a much greater proportion of bog with improved flowage facilities than Barnstable County has. A similar development of flowage facilities in the other counties during this period is shown in Table 3.

TABLE 4. — PERCENTAGES OF TOTAL BOG AREA WITH DIFFERENT FLOWAGE FACILITIES

Type of Flowage Protection	Percentages of Bog Acreage in —					
	State Total		Barnstable County		Plymouth County	
	1924*	1934	1924**	1934	1924	1934
Full flowage	45.3	48.4	24.7	31.0	55.0	54.7
Winter and two spring flowages	1.6	9.0	.5	3.3	2.2	9.5
Winter and one spring flowage	6.2	12.8	2.3	16.4	8.5	12.2
TOTAL of the better types of flowage	53.1	70.2	27.5	50.7	65.7	76.4
Winter flowage only	34.6	24.5	47.7	39.9	28.0	19.6
Dry bog	10.9	5.3	21.4	9.4	6.3	4.0
TOTAL, dry bog and winter flowage only	45.5	29.8	69.1	49.3	34.3	23.6

* 1.4 percent of the acreage was not classified.

** 3.4 percent of the acreage was not classified.

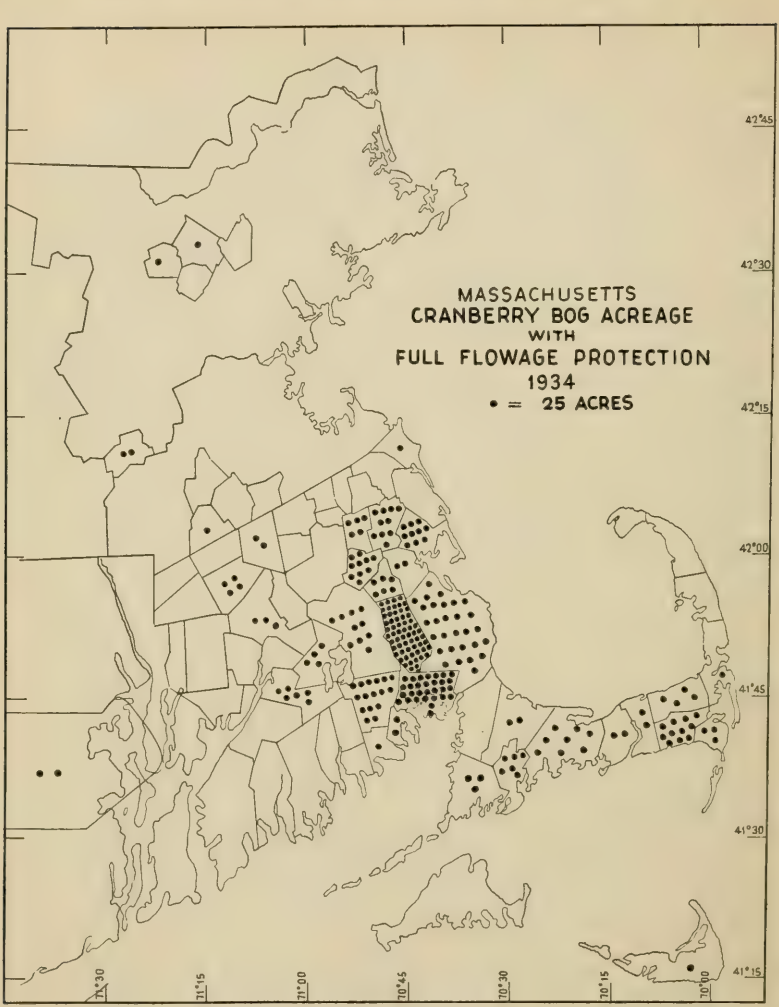

MASSACHUSETTS
CRANBERRY BOG ACREAGE
WITH
FULL FLOWAGE PROTECTION
1934
• = 25 ACRES
42°45
42°30
42°15
42°00
41°45
41°30
41°15
71°30
71°15
71°00
70°45
70°30
70°15
70°00

Figure 3.

CRANBERRY BOG PUMPING PLANTS

Bogs generally are flooded either by pumping or by gravity flow from a pond, stream, or reservoir, but those with winter flowage only are often flooded by the accumulation of the water from rains and melting snows. When pumps are used for flooding, the water usually is pumped on the bog and drained off by gravity, but in some cases this is reversed. Some bogs are flooded repeatedly with the same water saved by pumping back into a reservoir.

The survey included a total of 398 pumping plants. Of these, 84 had electric motors and the rest were operated by gasoline engines. The horsepower of the electric motors ranged from 6 to 100, with a total of 2,707 and an average of 32.2; of the gasoline engines, from 3 to 271, with a total of 9,312 and an average of 29.7. Table 5 gives a number of facts about the installations.

Table 5. — Massachusetts Cranberry Bog Pumping Plants in 1934

Lift, Feet	Electric			Gasoline			All		
	Number of Plants	Acres	Horsepower	Number of Plants	Acres	Horsepower	Number of Plants	Acres	Horsepower
1	1	2.5	4	6	21.5	140	7	24.0	144
2	9	135.5	192	30	295.1	799	39	430.6	991
3	8	52.1	215	51	373.8	1,352	59	425.9	1,567
4	9	100.5	222	56	484.7	1,469	65	585.2	1,691
5	8	69.2	182	52	706.9	1,409	60	776.1	1,591
6	21	527.4	682	36	379.0	1,114	57	906.4	1,796
7	1	6.0	30	21	166.3	582	22	172.3	612
8	7	221.5	300	29	412.9	1,276	36	634.4	1,576
9	6	85.5	205	4	30.2	164	10	115.7	369
10	4	105.5	240	8	93.1	438	12	198.6	678
11	1	14.5	40	4	30.5	125	5	45.0	165
12	3	22.5	55	10	100.5	218	13	123.0	273
13	2	38.8	120	0			2	38.8	120
14	1	19.0	60	4	48.2	111	5	67.2	171
15	2	30.5	110	1	43.0	40	3	73.5	150
18	0			1	7.0	10	1	7.0	10
22	0			1	15.0	65	1	15.0	65
24	1	14.5	50	0			1	14.5	50
TOTAL	84	1,445.5	2,707	314	3,207.7	9,312	398	4,653.2	12,019

"Lift," as used in the survey, is the difference in elevation between the pond level and the level of the water on the bog when it is completely flooded. As there are a number of plants listed as having only a 1-foot lift, it is likely that this definition was not used in all cases. The lift varied from 1 foot to 24 feet, with an average of 5.6. Table 5 shows that most of the plants had lifts of from 3 to 6 feet and that few plants had lifts of more than 8 feet.

The individual plants showed a wide range in power provided for bogs of equal acreage and equal lift. A fairly close coordination is expected between horsepower and "acres x lift," but there was great variation in this ratio for individual plants. For example, on the 6-foot lift, a 1-acre bog was equipped with a 30-horsepower motor, while an 80-acre bog was equipped with a 25-horsepower motor. As an average, .288 horsepower was provided per "acre x lift" for electric installations, .537 for gasoline installations, and .461 for all installations.

It is interesting to compare the actual installations with what may be considered theoretically required or desirable. Assuming that bogs are to be flooded to an average depth of 12 inches in 4 hours and that the ditches are full to the level of the bog at the beginning of the 4-hour period, a pumping capacity of 1,360 gallons a minute is required per acre. Assuming a pump efficiency of 70 percent, the power requirement is .489 horsepower per "acre x lift." If the efficiency of the pump is 35 percent, the power required will, of course, be .978 horsepower, which is about twice the average power provided per "acre x lift" for the State as a whole. The pumping plants in Barnstable County averaged slightly larger than this theoretical requirement, and those in Plymouth County were much smaller. The survey does not show the efficiency of the various pumps, but it is well known that many pumps have low efficiencies and many engines do not develop their rated horsepower. The average cranberry-bog pumping plant probably operates with 35 to 50 percent efficiency.

Table 6 gives detailed information on the pumping plants in the various counties. There were 83 electric-driven pumps in Plymouth County, one in Barnstable County, and none in Bristol or Nantucket Counties.

TABLE 6. — MASSACHUSETTS CRANBERRY BOG PUMPING PLANTS IN 1934, BY COUNTIES

Lift, Feet	Electric			Gasoline			All		
	Number of Plants	Acres	Horsepower	Number of Plants	Acres	Horsepower	Number of Plants	Acres	Horsepower
				Barnstable County					
1	0			5	20.0	120	5	20.0	120
2	0			17	69.6	485	17	69.6	485
3	1	1.5	10	28	183.7	680	29	185.2	690
4	0			19	114.0	520	19	114.0	520
5	0			10	108.5	215	10	108.5	215
6	0			9	73.8	385	9	73.8	385
7	0			8	56.5	266	8	56.5	266
8	0			6	27.0	150	6	27.0	150
9	0			1	21.0	80	1	21.0	80
10	0			1	4.0	40	1	4.0	40
11	0			1	21.0	60	1	21.0	60
12	0			1	3.5	35	1	3.5	35
TOTAL	1	1.5	10	106	702.6	3,036	107	704.1	3,046
				Bristol County					
3	0			1	10.0	30	1	10.0	30
4	0			1	2.0	22	1	2.0	22
6	0			1	1.5	16	1	1.5	16
TOTAL	0			3	13.5	68	3	13.5	68
				Nantucket County					
2	0			1	75.0	30	1	75.0	30
5	0			1	150.0	30	1	150.0	30
6	0			1	25.0	25	1	25.0	25
TOTAL	0			3	250.0	85	3	250.0	85
				Plymouth County					
1	1	2.5	4	1	1.5	20	2	4.0	24
2	9	135.5	192	12	150.5	284	21	286.0	476
3	7	50.6	205	22	180.1	642	29	230.7	847
4	9	100.5	222	36	368.7	927	45	469.2	1,149
5	8	69.2	182	41	448.4	1,164	49	517.6	1,346
6	21	527.4	682	25	278.7	688	46	806.1	1,370
7	1	6.0	30	13	109.8	316	14	115.8	346
8	7	221.5	300	23	385.9	1,126	30	607.4	1,426
9	6	85.5	205	3	9.2	84	9	94.7	289
10	4	105.5	240	7	89.1	398	11	194.6	638
11	1	14.5	40	3	9.5	65	4	24.0	105
12	3	22.5	55	9	97.0	183	12	119.5	238
13	2	38.8	120	0			2	38.8	120
14	1	19.0	60	4	48.2	111	5	67.2	171
15	2	30.5	110	1	43.0	40	3	73.5	150
18	0			1	7.0	10	1	7.0	10
22	0			1	15.0	65	1	15.0	65
24	1	14.5	50	0			1	14.5	50
TOTAL	83	1,444.0	2,697	202	2,241.6	6,123	285	3,685.6	8,820

TABLE 7. — SUMMARY OF MASSACHUSETTS CRANBERRY BOG PUMPING PLANTS IN 1934, BY COUNTIES

County	Acres Flowed	Number of Plants	Lift, Feet		Total Horsepower	Average Horsepower per Plant	Average Horsepower per "Acre x Lift"
			Range	Average			
Barnstable	704.1	107	1 to 12	4.2	3,046	28.5	1.03
Plymouth	3,685.6	285	1 to 24	6.2	8,820	31.0	0.39
Bristol	13.5	3	3 to 6	4.3	68	22.6	1.17
Nantucket	250.0	3	2 to 6	4.3	85	18.3	0.08
STATE TOTAL	4,653.2	398	1 to 24	5.6	12,019	30.2	0.46

Table 7 summarizes pumping plants by counties, showing number of acres flowed, number of plants, lift, and horsepower provided.

Table 8 summarizes for the entire State, showing the number of pumps driven by electric motors and the number operated by gasoline engines, with pertinent facts as to size of units, lift, and acres flowed. It appears that 4,653 acres, fully a third of the entire cranberry acreage of the State, is flooded by pumping.

TABLE 8. — COMPARATIVE USE OF GASOLINE AND ELECTRICITY IN MASSACHUSETTS CRANBERRY-BOG PUMPING PLANTS IN 1934

	Electric Pumps	Gasoline Pumps	All Pumps
Number of plants	84	314	398
Acres flowed by pumps	1,445	3,208	4,653
Average acres flooded per pump	17.2	10.2	11.7
Average lift, feet	6.5	5.4	5.6
Average "acre x lift"	112	55	65
Total horsepower	2,707	9,312	12,019
Average horsepower per plant	32.2	29.7	30.2
Average horsepower per "acre x lift"	.288	.537	.461

CRANBERRY VARIETIES GROWN

Table 9 gives the Massachusetts cranberry acreage by counties and varieties. Both Early Black and Howes are very much more important than all the remaining varieties combined. Together they make up 88 percent of the entire acreage. Early Black is the standard early variety and Howes the standard late one. They will remain supreme for a long time, not only because of their lead in acreage but also because their fruit is favorably known by the trade everywhere. They are the oldest of the cultivated varieties and their enduring supremacy reflects great credit on the keen selective sense of the pioneers of the industry. They have been widely planted in New Jersey also.

McFarlin holds third place in the State's acreage by only a small margin over Smalley Howes, but it has been planted much more extensively than any other Massachusetts variety in Wisconsin and on the Pacific Coast. There is a fairly substantial acreage of Matthews, Bugle, and Early Red. Shaws Success is the best of the midseason varieties, and Aviator is the most promising of the newer ones.

TABLE 9. — MASSACHUSETTS CRANBERRY ACREAGE IN 1934, BY COUNTIES AND VARIETIES

Variety	Barnstable	Bristol	Dukes	Essex	Middlesex	Nantucket	Norfolk	Plymouth	Worcester	State Total
Early Black	1,832.9	217.4	9.7	2.0	23.0	89.0	23.5	4,436.9	2.0	6,636.4
Howes	906.7	217.9	5.8	8.0	54.7	200.8	30.0	3,947.5	2.0	5,373.4
McFarlin	30.3	8.5	4.5				1.0	178.2		222.5
Smalley Howes	171.5							45.8		217.3
Matthews	122.6	.3					.2	58.5		181.6
Bugle	90.4						.2	48.9		139.5
Early Red	32.5	2.3					2.2	66.9		103.9
Holliston	18.1	7.8			6.0		.5	46.9		79.3
Centennial	3.4				17.0			36.2		56.6
Centerville	21.0		1.7			1.5		21.5		45.7
Pride			.5					31.5		32.0
Wales Henry		2.5						24.8		27.3
Smith	26.5									26.5
Black Veil	.2					1.2		19.2		20.6
Chipman	2.0							13.5		*15.5
Shaws Success	.5							13.0		13.5
Berry Berry								13.3		13.3
Perry Red								12.0		12.0
Middlesex					12.0					12.0
Paradise Meadow							9.0			9.0
Middleboro								8.7		8.7
Stanley								8.0		8.0
Pointed Howes								6.5		6.5
Round Howes	5.0							1.5		6.5
Champion	4.0							2.0		6.0
Winslow	5.0									5.0
Hockanum							4.8	.1		4.9
Whiting Randall								4.0		4.0
Maxim Randall		.7						1.3		2.0
Leonard Robbins	1.5									1.5
Buckalew	.5							1.0		1.5
Shurtleff								1.2		1.2
Rhode Island								1.0		1.0
Howland	1.0									1.0
Whitman Park							.8			.8
Kelley							.5			.5
Aviator								.5		.5
Nova Scotia Bell								.5		.5
Indian Head								.3		.3
Gifford								.2		.2
Brook Farm							.2			.2
Murdock								.2		.2
Snipatuit								.2		.2
Hall								.2		.2
Mixed or Unnamed	224.4	6.6	39.8	4.0	15.3	11.5	1.1	39.0	3.0	344.7
TOTAL	3,500.0	464.0	62.0	14.0	128.0	304.0	74.0	9,091.0	7.0	13,644.0

* As the growers have long confused the Chipman Variety considerably with the Bugle, this acreage may not be accurate. There may be as much as 25 acres of Chipman, perhaps mostly in Barnstable County.

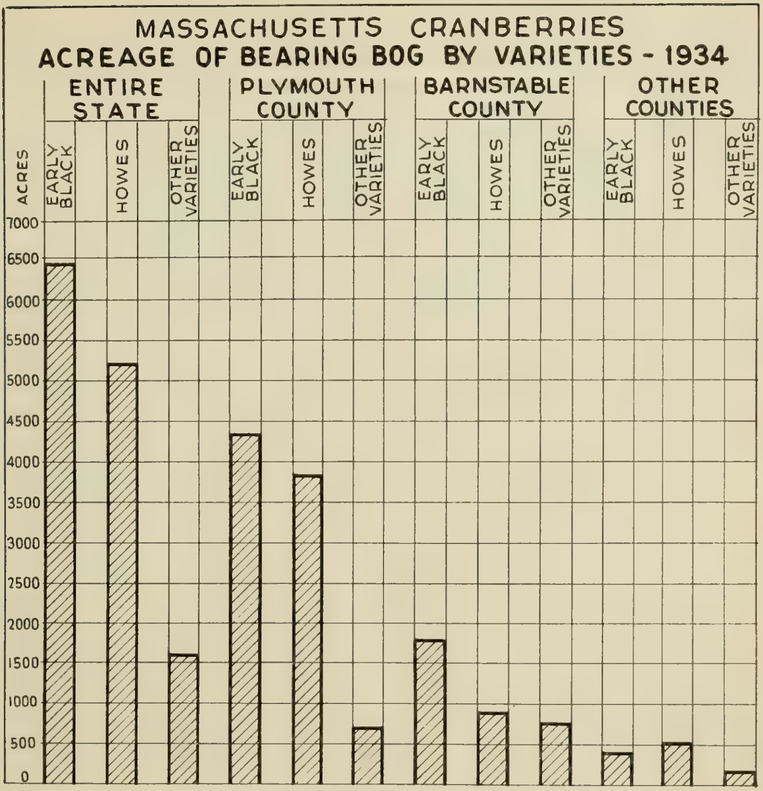


Figure 4.

TABLE 10. — ACREAGE OF NEW AND REBUILT BOG BY COUNTIES AND VARIETIES — 1934

County	New Bog Built since January, 1932					Old Bog Rebuilt since January, 1932				
	Early Black	Howes	McFarlin	Other Varieties	Total	Early Black	Howes	McFarlin	Other Varieties	Total
Barnstable	33.5	0.9		0.6	35.0	40.6	29.3		7.2	77.1
Bristol	11.9	7.5			19.4	.5				.5
Dukes						1.0	1.5			2.5
Middlesex		1.5			1.5				11.0	11.0
Nantucket						.5				.5
Norfolk						2.0				2.0
Plymouth	69.3	43.0	4.0	.8	117.1	61.1	94.2	3.3	6.8	165.4
Worcester	2.0				2.0		1.0			1.0
STATE TOTAL	116.7	52.9	4.0	1.4	175.0	105.7	126.0	3.3	25.0	260.0

Figure 4 shows the acreage of bearing bog in the State in 1934 by counties and principal varieties. Table 10 and Figure 5 give the acreages of new bog planted and old bog rebuilt in 1932 and 1933, by counties and varieties; and show that the growers are still interested almost exclusively in Early Black and Howes.

The relative sales by the New England Cranberry Sales Company of Early Black, Howes, and miscellaneous varieties from 1914 to 1934 are given in percentages in Table 11. For the three years covered by the survey, this Company handled about 56 percent of the entire Massachusetts crop, and Early Blacks and Howes made up an average of 92 percent of its sales. In 1917, a large part of the Early Blacks were sold as miscellaneous because they were injured by a severe freeze in early September.

Table 11. — Percentage of Sales of New England Cranberry Sales Company Classed as Early Black, Howes, and Miscellaneous

1914 — 1934

Year	Early Black	Howes	Miscellaneous
1914	52.1	31.5	16.4
1915	45.8	36.4	17.8
1916	50.8	31.8	17.4
1917	36.3	28.3	35.4
1918	54.0	28.6	17.4
1919	48.9	34.4	16.7
1920	53.0	30.4	16.6
1921	45.4	36.6	18.0
1922	52.0	31.5	16.5
1923	50.4	33.7	15.9
1924	49.2	42.0	8.8
1925	52.2	41.6	6.2
1926	54.3	38.3	7.4
1927	55.2	37.6	7.2
1928	49.4	41.9	8.7
1929	48.0	42.7	9.3
1930	51.0	40.1	8.9
1931	52.3	39.8	7.9
1932	48.1	43.4	8.5
1933	56.4	36.3	7.3
1934	54.3	38.2	7.5

CRANBERRY PRODUCTION

The earliest consistent effort to get accurate estimates of cranberry production for each of the three main centers of the industry was that made by N. R. French, Statistician for the New Jersey Cranberry Growers' Association, which later became the American Cranberry Growers' Association. This Association was organized in 1869, and the reports of their annual convention contain estimates of the crop beginning with the year 1872 for New England, New Jersey, the West, and New York. No check-up of these estimates against shipments was made, however, until 1883. In Table 17 (in the appendix), the figures for the years 1872 to 1882, inclusive, are estimates only and are taken from the Proceedings of the Seventeenth Annual Convention of the American

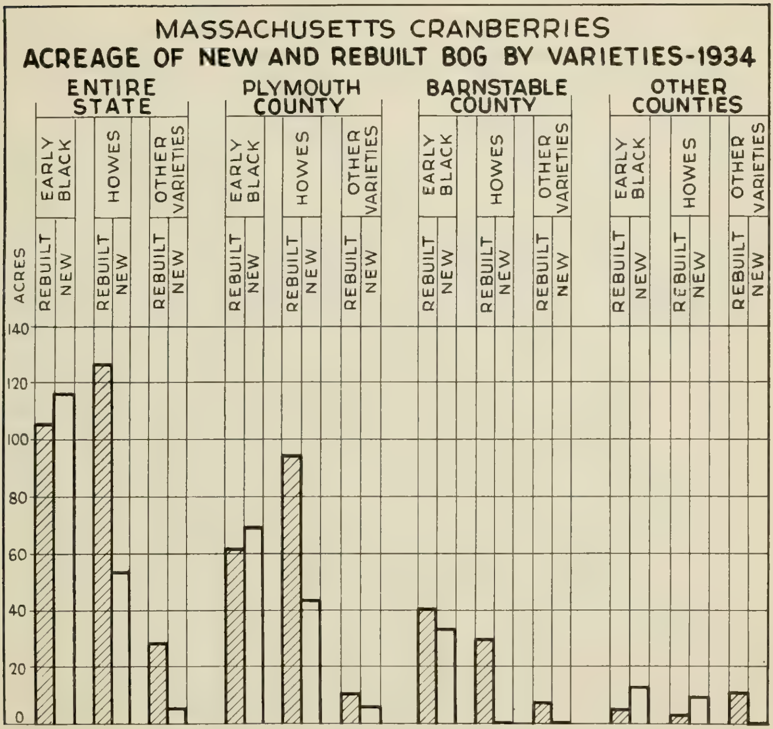


Figure 5.

Cranberry Growers' Association held September 4, 1886. The figures for the years 1883 to 1888, inclusive, are actual shipments as given in the report of the Twentieth Annual Convention of the American Cranberry Growers' Association held August 27, 1889. The figures for the year 1889 are taken from the same report but are only estimates. The figures for the years 1890 to 1900 are taken from the annual report of the New Jersey State Board of Agriculture for 1901, but were received from the American Cranberry Growers' Association. These are, presumably, shipments, though the report does not say so. The figures were in bushels or crates, but have been converted into barrels for the sake of uniformity; three bushels or crates equal one barrel. The figures for the years 1867, 1868, and 1869 were taken from the annual report of the United States Department of Agriculture for 1869.

Figure 6 presents graphs of the changes in the yearly cranberry production of New England, New Jersey, the West, and the entire United States from 1867 to 1900, inclusive. As will be seen, the production of New England and New Jersey, though fluctuating violently at times, increased rather steadily throughout this period, while that of the West showed no definite trend.

Figure 7 illustrates the changes in the annual cranberry production of the three principal producing States and the entire country since 1900. See also Table 18 (in appendix). In general, the crops of Massachusetts and Wisconsin have increased during the period, while those of New Jersey and the Pacific Coast have trended downward. The main difficulty in New Jersey has been the prevalence of the false blossom disease in recent years. This has greatly

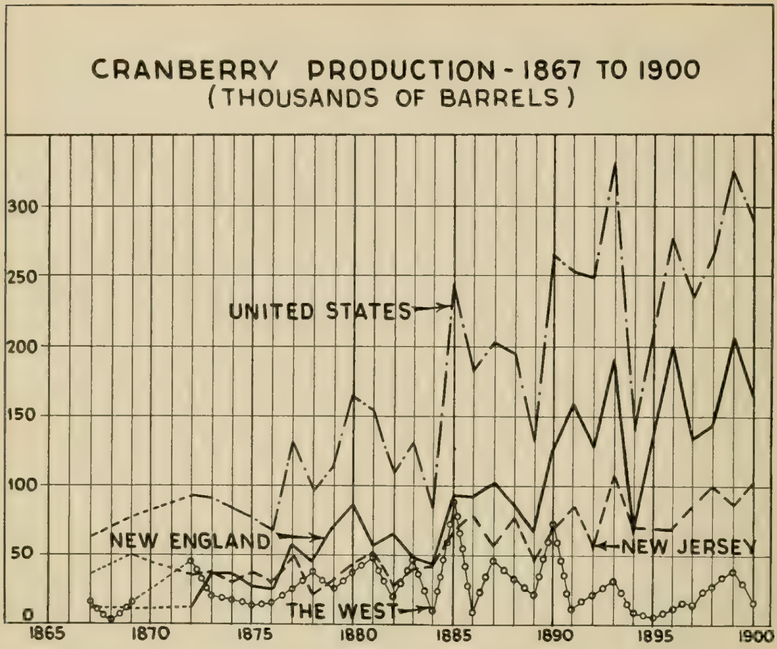


Figure 6.

reduced the yield on a large acreage there. Frosts have been very destructive on the Pacific Coast.

The upward trend in Massachusetts is of interest, for it has been accomplished in spite of some reduction in acreage and the development here of three new major enemies of the cranberry industry: the false blossom disease, the gipsy moth, and the root grub. The increased production was apparently due mostly to the improvement of flowage facilities and the more general adoption of better cultural practices.

The record of cranberry production in Massachusetts since 1900 is given in Table 12, together with revised estimates of total acreage for each year. The annual average yield per acre, season average price, crop value, recorded shipments, and the level of business activity of the country are also included for comparative purposes. During this period, cranberry production in Massachusetts has shown a consistent upward trend except as interrupted by unfavorable labor and market conditions caused by the World War. Cranberry production increased from an average of 271,900 barrels annually for the ten years 1901–1910 to an annual average of 317,000 barrels from 1911–1920 in spite of the decrease in some of the war years. A further increase to an average of 376,900 barrels per year is shown for the period 1921–1930, while the average of the past five years, 1931–1935, is 400,600 barrels. Since 1900 the smallest Massachusetts cranberry crop was harvested in 1917 and totaled only 137,000 barrels, while the largest crop on record occurred in 1933 with a total of 506,000 barrels. The lowest average yield per acre since 1900 was 9.7 barrels in 1917 and the highest 36.9 barrels in 1933. The average yield per acre for the entire period was 24.2 barrels and the average for the five years 1931–1935 was 29.2 barrels.

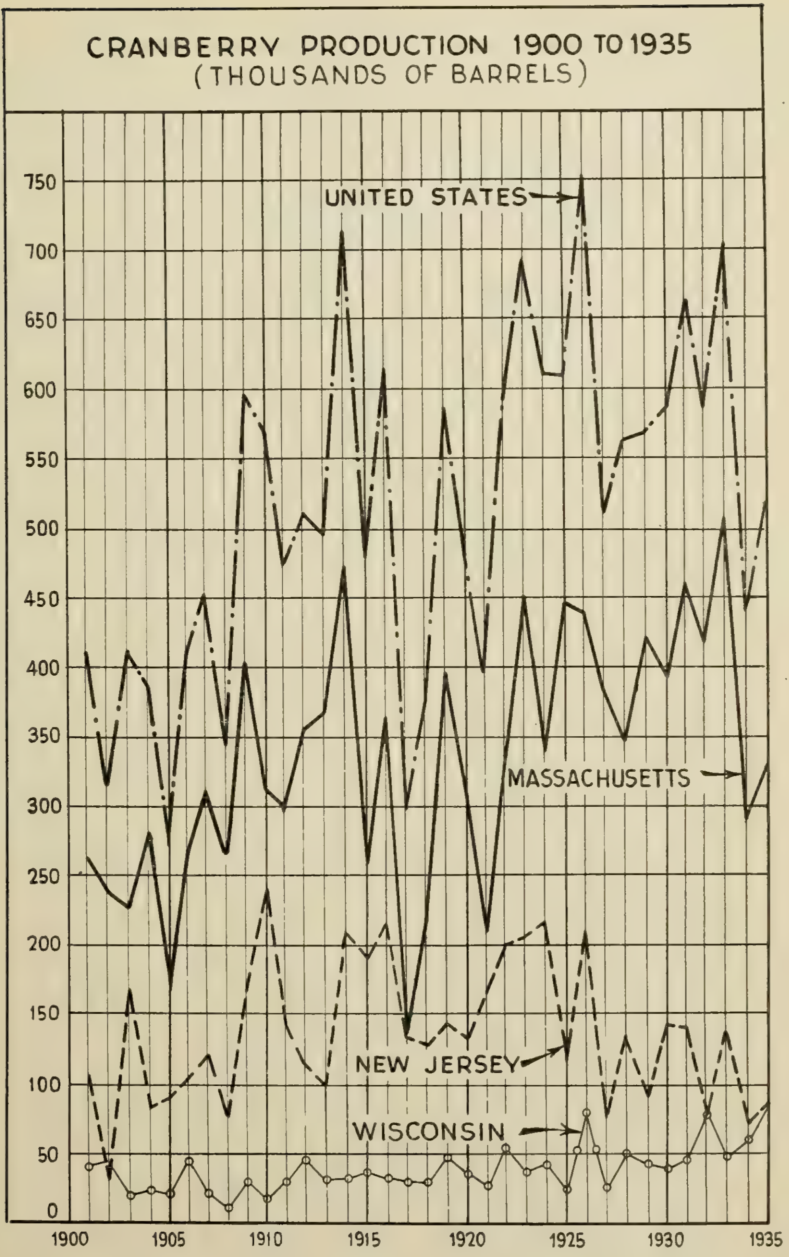


Figure 7.

It is of interest to note here that the noticeably low yields of 1915, 1917, 1918, and 1921 were all caused mostly by destructive frosts (see pp. 21 and 22,) while that of 1905 was due largely to extraordinary fruit-worm activity. The downward trend in production from 1914–1921 was due primarily to war conditions. The scarcity and high cost of labor and the uncertainty about cranberry demand because of sugar scarcity caused the growers generally to neglect their bogs. Neglect of resanding made the bogs not protected by flooding more liable to frost injury and resulted generally in poorer vine growth and increased trouble with the cranberry girdler.

TABLE 12. — MASSACHUSETTS CRANBERRIES: ACREAGE, YIELD, PRODUCTION, PRICE, VALUE, SHIPMENT RECORDS, AND BUSINESS ACTIVITY, 1901 — 1935

Years	Total Acres	Yield Per Acre Barrels*	Production in Barrels	Season Average Price Per Barrel	Total Crop Value in Thous. Dollars	C.L. and L.C.L. Shipments reported by NY, NH & H RR Barrels	Index of Business Activity†
1901	11,700	22.6	264,000	$ 5.50	$1,452	240,000	103.5
1902	12,000	19.8	238,000	6.20	1,476	215,000	106.0
1903	12,300	18.4	226,000	6.00	1,356	204,000	94.0
1904	12,700	22.1	281,000	5.00	1,405	257,000	97.5
1905	13,000	12.7	165,000	7.50	1,238	146,000	108.5
1906	13,300	19.8	264,000	6.30	1,663	240,000	111.2
1907	13,500	23.0	310,000	6.30	1,953	284,238	99.0
1908	13,700	18.8	257,000	7.50	1,928	233,791	89.0
1909	13,900	28.9	402,000	5.30	2,131	373,622	109.0
1910	14,000	22.3	312,000	5.60	1,747	287,046	96.5
1911	14,100	21.1	298,000	6.90	2,056	273,140	95.5
1912	14,100	25.1	354,000	6.50	2,301	328,036	108.5
1913	14,200	25.8	367,000	6.20	2,275	341,235	97.8
1914	14,200	33.2	471,000	4.00	1,884	435,296	84.5
1915	14,200	18.1	257,000	6.40	1,645	235,232	108.2
1916	14,100	25.8	364,000	6.50	2,366	337,755	112.2
1917	14,100	9.7	137,000	10.00	1,370	116,917	103.2
1918	14,100	15.5	218,000	8.70	1,897	194,507	104.0
1919	14,000	28.2	395,000	7.90	3,120	365,406	106.9
1920	14,000	22.1	309,000	10.30	3,183	274,742	97.9
1921	14,000	14.9	208,000	12.90	2,683	182,169	84.2
1922	14,000	24.1	337,000	10.50	3,538	292,799	103.8
1923	14,000	32.2	451,000	7.90	3,563	377,968	106.0
1924	13,900	24.4	339,000	10.00	3,390	276,064	101.0
1925	13,900	32.2	447,000	10.90	4,872	378,346	109.0
1926	13,900	31.5	438,000	7.20	3,154	365,112	111.0
1927	13,900	27.7	385,000	12.80	4,928	321,946	103.6
1928	13,800	25.2	348,000	14.40	5,011	265,296	111.5
1929	13,800	30.5	421,000	13.40	5,641	336,657	108.9
1930	13,800	28.6	395,000	10.90	4,306	312,970	86.2
1931	13,800	33.3	460,000	6.50	2,990	362,612	73.3
1932	13,700	30.3	415,000	7.70	3,196	304,326	65.0
1933	13,700	36.9	506,000	6.30	3,188	358,974	71.6
1934	13,700	21.2	290,000	11.30	3,277	212,893	71.5
1935‡	13,700	24.2	332,000	11.50	3,818	218,728	88.7

* Derived

‡Preliminary

† Four months average (Sept.–Dec. inclusive) of Axe Houghton Business Index 1901 to 1918 and The Annalist Index of Business Activity 1919 to 1935 adjusted for long-time trend.

Since 1920 the lower cost of sugar and an aggressive marketing and advertising policy have resulted in a better demand and higher prices for cranberries. This has encouraged the growers to give much more attention to the care of their properties.

Table 19 (in appendix) gives the average yield per acre and the total production of Massachusetts cranberries by main varieties and counties in 1931, 1932, and 1933, the years immediately preceding the 1934 survey. In yield per acre, Plymouth County led all the counties with a considerable cranberry acreage, with Bristol and Middlesex Counties in second and third place respectively.

The yields per acre of the Early Black variety were generally materially greater than those of the Howes variety, but in Bristol and Norfolk Counties the Howes variety led the Early Black every year. Other varieties, taken together, generally yielded considerably less than either Early Black or Howes, but they led those varieties very definitely in Norfolk County each year. The three-year average yield of all varieties and counties was 34.8 barrels per acre.

FROST INJURY OF MASSACHUSETTS CRANBERRY BOGS

The following record shows the frosts which have done material harm on the Cape Cod cranberry bogs in the years 1910–1935, inclusive.

Year	Date of Spring Frosts	Date of Fall Frosts	Range of Temperature on Bogs	Remarks
1910	April 28		17°–23°F.	Estimated loss 35 percent.
1911				No official record.
1912				No official record.
1913	May 14		20°–30°F.	Considerable damage on bogs in some localities, especially inland, and particularly at South Hanson and Norton.
	June 9		26°–38°F.	Considerable injury on bogs in some localities, especially in South Hanson and Harwich.
		Sept. 15	20°–29°F.	Damage most severe in Carver. 40,000 barrels estimated frozen.
1914	June 5		26°–30°F.	Estimated loss 12,000 barrels.
		Sept. 10–14	26°–31°F.	Estimated loss 25,000 barrels. Loss on New Jersey bogs, 50,000 barrels
1915	May 27		27°–36°F.	Principal injury inland, especially in Rochester. Estimated loss 4 percent.
	May 29		21°–28°F.	Estimated injury 40 percent.
1916				Very little frost damage.
1917		Sept. 10	21°–26°F.	Estimated injury 50 percent, mostly in Plymouth and Bristol Counties. No frost in most of Barnstable County. Estimated injury on New Jersey bogs 25 percent.
		Sept. 11	21°–26°F.	Estimated injury 10 percent, mainly in Barnstable County.

Year	Date of Spring Frosts	Date of Fall Frosts	Range of Temperature on Bogs	Remarks
1918	June 20		21°–27°F.	Estimated loss 55 percent. This severe frost came so late in the season that it harmed the vines of many bogs so that they failed to bud properly to produce a crop the following year, that is, in 1919.
1919				Only slight damage from frost. There was some carry-over of injury from the June frost of 1918.
1920				No frost damage on the bogs.
1921	May 11		18°–24°F.	Estimated loss 5 percent, mostly around South Hanson. This frost killed strawberry blossoms quite generally and also many blueberry blossoms.
	May 24		23°–32°F.	Estimated loss 15 percent, mostly in Barnstable County.
1922	May 27		25°–32°F.	Estimated loss 20 percent.
		Sept. 18	21°–30°F.	Estimated loss 10,000 barrels.
1923	May 23		26°–29°F.	Loss considerable but not estimated.
1924	May 31		26°–30°F.	Estimated loss 7 percent.
1925	May 25		23°–27°F.	Estimated loss 5 percent. On New Jersey bogs, estimated loss 15 percent.
		Aug. 27	24°–34°F.	3,000 barrels estimated frozen.
		Sept. 22	18°–27°F.	3,000 barrels estimated frozen.
		Sept. 25	14°–24°F.	4,000 barrels estimated frozen.
		Sept. 30	12°–20°F.	4,000 barrels estimated frozen.
1926				Very little frost injury.
1927	June 3		25°–32°F.	Estimated loss 2 percent.
	July 4		28°–32°F.	Slight loss.
1928				Very little injury.
1929	May 22		18°–30°F.	Estimated injury 6 percent.
	July 3		29°–34°F.	Estimated loss 1,500 barrels, all in Norton.
		Oct. 8-10	8°–23°F.	500 barrels frozen.
1930	May 30 and 31		20°–30°F.	Estimated loss 3 percent.
1931				No injury.
1932	May 23		24°–29°F.	Estimated injury 4 percent.
1933	May 17		23°–32°F.	Only slight injury.
		Oct. 14	20°–27°F.	Only slight injury.
1934	April 28		15°–19°F.	Estimated injury 8 percent.
1935				Little injury.

This record covers twenty-six years. The estimates of loss in every case were made up from information secured from the cranberry growers at the time of occurrence. Injury to cranberry bogs by frost occurred in the spring as early as April 28 and as late as July 4. In the 26-year period, frosts did damage 2 nights in April, 14 nights in May, 4 nights in June, and 2 nights in July, the bulk of the loss occurring from the middle of May to the twentieth of June. The cranberry vines are usually considerably resistant to frost injury till the middle of May, and frost seldom comes on Cape Cod after June 20.

In the period considered, damaging fall frosts occurred once late in August, 12 times in September, and 4 times in October, most of the injury being done from September 10 to 18. Severe frost rarely comes on the Cape before September 10, and by late September the berries are ripe enough to resist frost materially. Also, a large part of the crop is gathered by late September and most of what remains on the bogs can be easily protected.

Some very interesting facts are apparent from a study of this record when the continuous series for the period 1913 — 1934 is separated into two parts, 1913–1923, inclusive, and 1924–1934, inclusive, and a comparison made as to relative production and frost damage. For the period 1913–1923, the cranberry crop harvested averaged 319,000 barrels per year, with estimated losses from frost injury averaging 79,000 barrels per year when estimated percentage losses are converted to a barrel basis. In other words, during the period 1913–1923 the Massachusetts cranberry crop might easily have averaged about 398,000 barrels annually if no loss from frost had occurred. In contrast, harvested production averaged 404,000 barrels per year for the period 1924–1934, and losses were limited to an average of 14,000 barrels per year. On a percentage basis, an average of 19.8 percent of the potential cranberry crop in Massachusetts was lost during the period 1913–1923 because of frost damage, compared with an average loss of only 3.3 percent annually during the years 1924–1934.

The great difference in the amount of damage by frost in these periods is probably due largely to the marked improvement in flowage facilities shown elsewhere in this report and to better attention of the growers to the matter of frost protection.

MARKETING

Basic to accurate estimates of cranberry production are the annual records of the movement and utilization of the crop, such as railroad, truck, and boat shipments of fresh fruit and the quantity of berries canned. The most important of these are the railroad shipments, details of which are shown by counties in Table 20 in the appendix. The results of the present survey furnish an indication of the extent to which these records include the entire crop produced. It appears that, in the years included in the survey (1931–1933), about 3 to 4 percent of the crops produced does not appear in the records. The difference can be readily accounted for by: (1) direct shipment by growers to retailers in all cities and to wholesalers in small cities, for available records of truck shipments cover only berries moved to commission merchants and wholesalers in the larger cities; (2) local consumption of cranberries; and (3) occasional out-of-season railroad shipments of which no record would be secured regularly.

Figure 8 shows the changes in disposal of the Massachusetts cranberry crop from 1919 to 1934. Railroad shipments became steadily less important, declining from 93.2 percent in 1919 to 68.7 percent in 1933. Truck shipments, including some boat shipments, on the other hand, increased from 1.3 percent in 1919 to a maximum of 19.6 percent in 1932. Truck and boat shipments

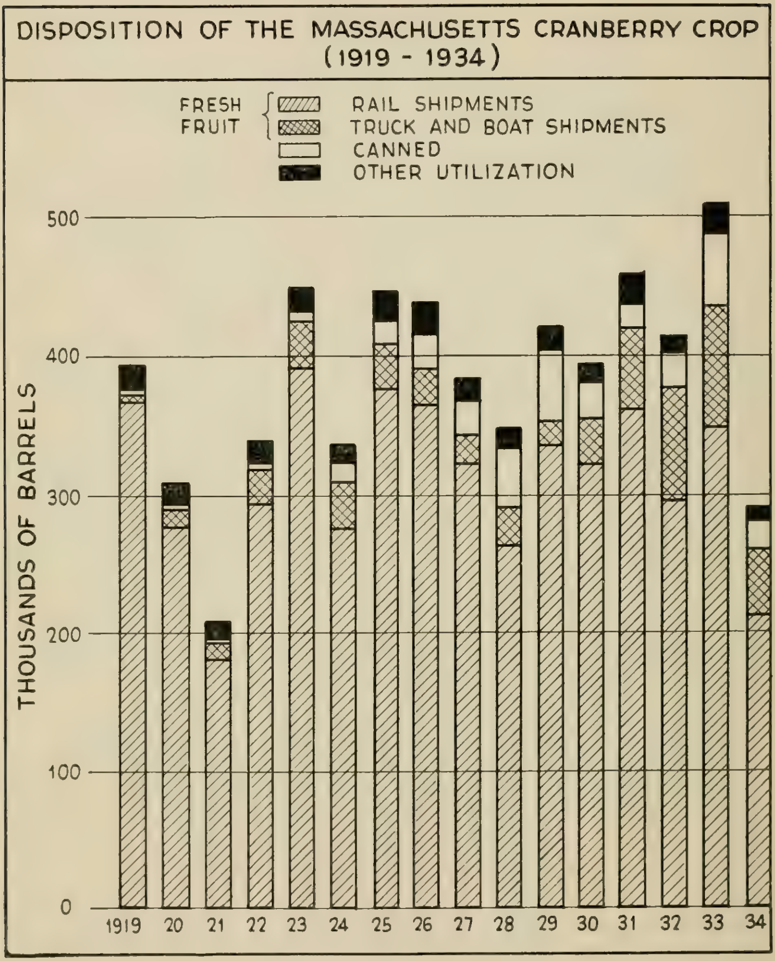


Figure 8.

showed a small relative reduction in 1933 and 1934. From a small beginning in 1919 of one half of one percent of the crop canned, the utilization of cranberries in this way increased steadily until 1928 when 12.7 percent was canned. During most of the recent years, 5 to 10 percent of the crop has been canned for later use.

Table 13 gives the numbers of cranberry growers who reported selling through the various marketing agencies. Local independent agents handled the berries of many more Barnstable County growers than any other kind of agency; but in Plymouth County, the New England Cranberry Sales Company led somewhat in the number of growers accommodated.

In the State as a whole, considerably fewer growers sold through the New England Cranberry Sales Company than through either local independent agents or Boston commission merchants. As only slightly over 20 percent of the growers sold through the Sales Company and this Company handled 56 percent of the crop, it is clear that its membership was largely made up of the larger growers.

The upper section of Figure 9 shows the monthly movement to market of Massachusetts cranberries sold through the New England Cranberry Sales Company and through other agencies. The percentage summations were made from the reports of the individual growers as to their usual practice in the years before the survey in 1934. The percentages for the New England Cranberry Sales Company are averages for the years 1931–1933, inclusive. They show that the Sales Company made relatively heavier shipments in September, December, and January than the other selling agencies, but that other shippers usually marketed much more rapidly in October and November than did the Sales Company. The shipments by both the Sales Company and others were greatest in October and November, reaching their maximum in November.

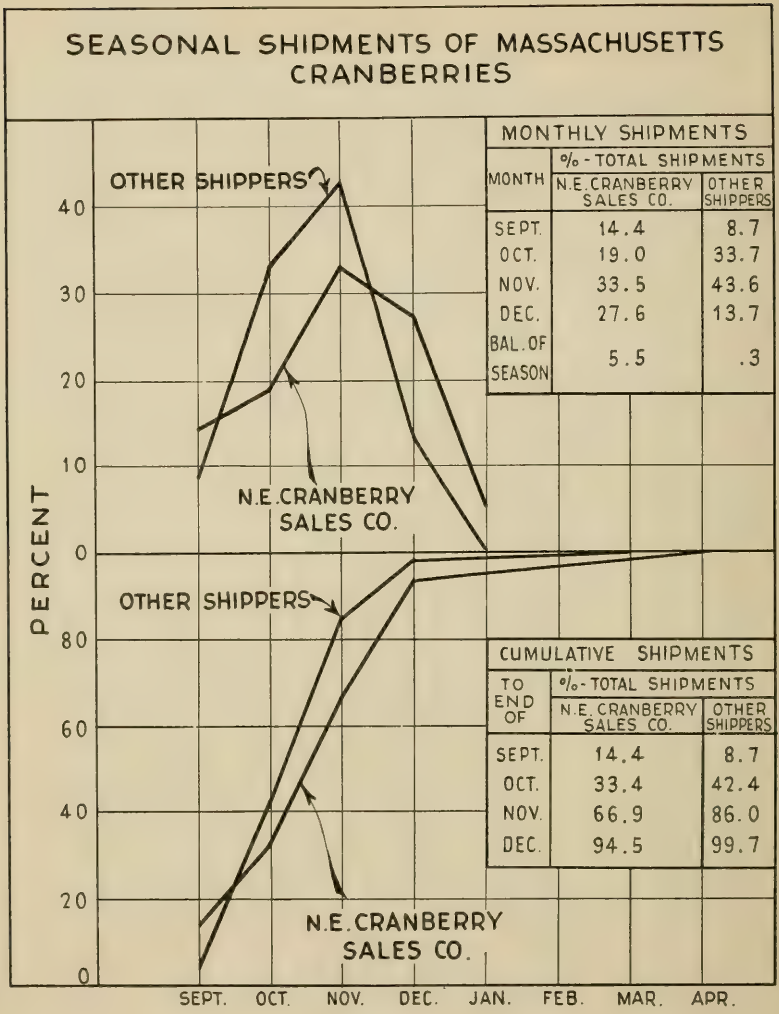
The lower part of Figure 9 shows the percentages of the crop shipped by the Sales Company and by other shippers up to the end of each month in the marketing season. At the end of November, the independent shippers had shipped 86 percent of their berries, while the Sales Company had forwarded only about 67 percent of their total.

TABLE 13. — NUMBER OF CRANBERRY GROWERS REPORTING SALES OF 1933 CROP, BY MARKETING AGENCIES

County	New England Cranberry Sales Co.	Local Independent Agents	Boston Commission Merchants	Merchants in other Cities	Duplicate	No Report
Barnstable	75	329	197	84	74	35
Bristol	8	2	8	9	2	2
Dukes	0	1	0	14	1	1
Essex	0	0	2	0	0	0
Middlesex	0	3	2	3	1	1
Nantucket	0	7	1	2	2	0
Norfolk	2	0	6	0	0	0
Plymouth	208	193	166	65	73	27
Worcester	0	1	0	1	1	1
In more than one county	7	1	3	1	0	0
STATE TOTAL	300	537	385	179	154	67

CRANBERRY PRICES

The factors affecting cranberry prices are of interest to all growers and handlers of this crop. Figure 10 compares the season average prices received by growers for the Massachusetts crop from 1901 to 1935 with cranberry production totals for the country as a whole and the level of business activity during the fall months (September to December, inclusive), when the bulk of the crop is marketed. With only five exceptions during this period, a larger crop of berries compared with that of the preceding year has been marketed at a lower price and a smaller crop at a higher price. In connection with most of the exceptions, it appears that a rise or fall in business activity has helped overcome the usual effect of production on prices. While it is evident that the level of business activity may affect the price at which the cranberry crop


SEASONAL SHIPMENTS OF MASSACHUSETTS CRANBERRIES

MONTHLY SHIPMENTS

MONTH	% - TOTAL SHIPMENTS	
	N.E. CRANBERRY SALES CO.	OTHER SHIPPERS
SEPT.	14.4	8.7
OCT.	19.0	33.7
NOV.	33.5	43.6
DEC.	27.6	13.7
BAL. OF SEASON	5.5	.3

CUMULATIVE SHIPMENTS

TO END OF	% - TOTAL SHIPMENTS	
	N.E. CRANBERRY SALES CO.	OTHER SHIPPERS
SEPT.	14.4	8.7
OCT.	33.4	42.4
NOV.	66.9	86.0
DEC.	94.5	99.7

Figure 9.

may be sold, the importance of production in determining prices points clearly to the need of having accurate forecasts of the crop early in the marketing season.

Since 1907 the American Cranberry Exchange has been an important factor in the marketing of the cranberry crop. Briefly, the American Cranberry Exchange started in 1907 when the new cranberry sales companies in Massachusetts, New Jersey, and Wisconsin jointly created a selling corporation known as the National Fruit Exchange and according to their estimates distributed 34 percent of the total crop of the country. A period of competition with the Growers' Cranberry Company followed. This ended in 1911 when the two companies united to form the American Cranberry Exchange. The estimated percentage of the crop handled by the combined companies was 53

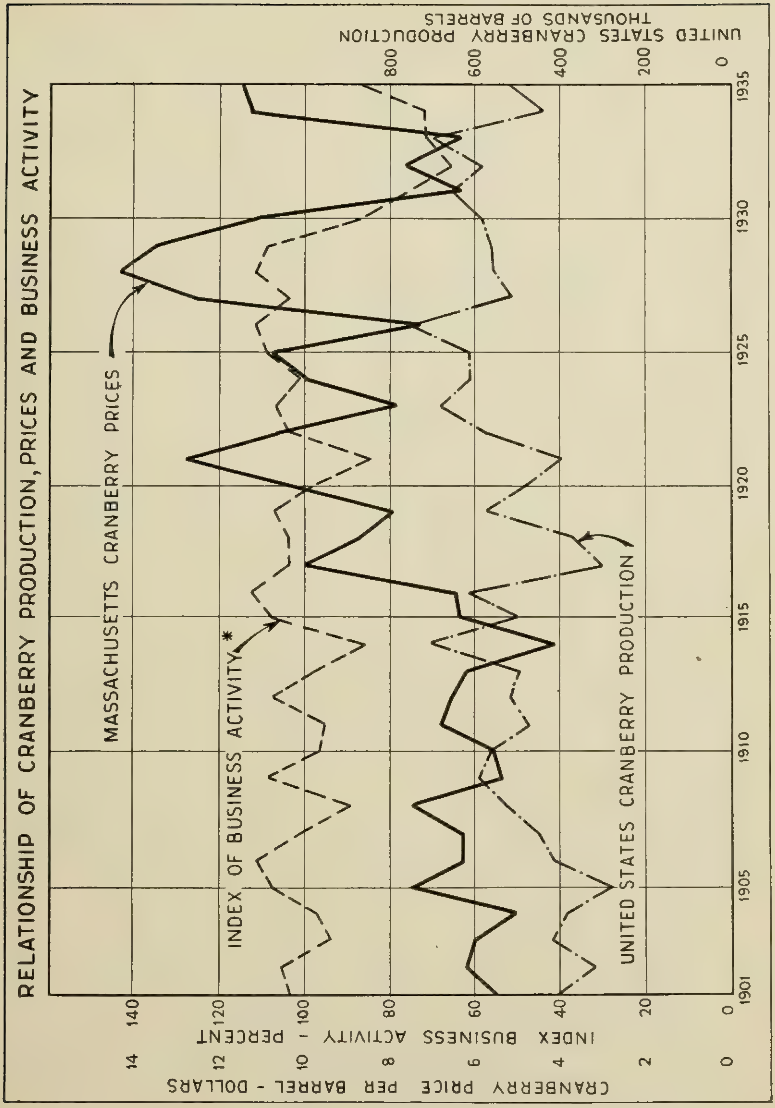


Figure 10

*From The Annalist - see Table 12

percent and this has shown some gradual increase since then. After some experimentation, the Exchange adopted a general program of advertising in 1918 which has been continued without interruption to the present time. For the past fifteen years cranberry prices have averaged considerably higher in spite of some increase in average production. It is believed that this can be credited largely to improved marketing practices which include the adoption of a smaller-sized package more suitable to market needs, advertising, and the removal of tender and thin-skinned berries from the fresh-fruit market by canning. Half-barrel boxes as cranberry containers were introduced to the trade about 1914 and by 1922 had largely displaced barrels. Quarter-barrel boxes, introduced in 1926, were used nearly as much as half-barrel boxes two years later and had almost completely replaced them by 1931. A record of cranberry prices before 1901 is given in Table 21 (in appendix).

The effective producing cranberry acreage of the country is now less than it has been at any time since 1905 due largely to the damage done by the false blossom disease, especially in New Jersey. On the other hand, population in the United States, where most of the crop is marketed, has increased from a total of seventy-six million persons in 1900 to one hundred and twenty-three million in 1930. This suggests that the cranberry industry is not over-expanded. If there were a light crop and generally prosperous conditions prevailed, cranberry prices might become high enough to curtail consumption seriously. This would tend to reduce the level of consumption in succeeding years when a wider market outlet might be needed for larger crops. It is also true that large cranberry crops in times of business depression reduce prices enough to make the business rather unprofitable. Canning of this fruit in recent years has tended to stabilize from year to year the quantity of cranberries available for consumption by extending the period during which large crops may be marketed. The practice of holding cranberries over in a frozen condition for use as they may be needed for canning has been especially helpful in this connection.

INSECTICIDES

Table 14 shows the insecticides used on Massachusetts cranberry bogs in 1933 and how much of each. As the growers used no contact poisons twenty-five years ago, depending almost entirely on flooding and lead arsenate to control pests, it is evident that they have greatly increased their facilities for insect warfare. There is still a large demand for lead arsenate, mainly to combat the gipsy moth, which pest is especially persistent in Barnstable County. Over twenty-three tons of this poison were applied to Massachusetts bogs and their surroundings in 1933.

TABLE 14. — INSECTICIDES USED ON MASSACHUSETTS BOGS IN 1933 - POUNDS

County	Stomach Poisons		Contact Poisons				
	Lead Arsenate	Paris Green	Nicotine Sulfate	Sodium Cyanide	Pyrethrum Dust*	Pyrethrum Extract	Pyrethrum Soap
Barnstable	24,349	104	1,062	323	23,904	790	7,367
Bristol	1,225	0	171	0	3,584	0	0
Dukes	0	0	0	0	450	0	0
Essex	0	0	0	0	0	0	0
Middlesex	0	0	0	0	0	0	0
Nantucket	1,344	0	20	0	6,830	0	0
Norfolk	0	0	0	0	0	0	0
Plymouth	19,450	372	1,938	11,584	197,545	2,456	5,552
Worcester	0	0	0	0	0	0	0
STATE TOTAL	46,368	476	3,191	11,907	232,313	3,246	12,919

* Mixtures of fine ground pyrethrum flowers and gypsum.

Since it was discovered that the blunt-nosed leafhopper is the main carrier of the false blossom disease, pyrethrum, especially pyrethrum dust, has become by far the leading cranberry insecticide, especially in Plymouth County.

Nicotine sulfate is now employed mainly against the spittle insect and the fruit worm. Ten to fifteen years ago it was an important control for the blackheaded fireworm, but pyrethrum has largely taken its place for this purpose.

The cranberry root grub is now treated largely with sodium cyanide. The importance of this pest and its relatively great prevalence in Plymouth County are shown by the fact that nearly six tons of the chemical were applied to the cranberry bogs of the State in 1933, all but 323 pounds being used in Plymouth County.

CRANBERRY LABOR

Information concerning the number of persons employed in the cranberry industry is often sought by the press and public organizations. This has not been available heretofore. Table 15 summarizes the relevant data gathered in the survey. As the industry employs a much larger number during the harvesting season than at any other time, and as most of those employed in other bog work are also engaged in picking the crop and preparing it for market, it may be assumed that the sum of those who pick the berries and sort them approaches the total employment. The table shows this sum for the whole State to be 20,118. The 104 employees of the canners added to this make a total for the industry in this State of 20,222 different persons employed yearly.

TABLE 15. — NUMBER OF PERSONS EMPLOYED BY MASSACHUSETTS CRANBERRY GROWERS AS REPORTED IN 1934 SURVEY*

County	Number of Year-round Employees		Number of Temporary Employees									
			Picking Crop		Hand Sorting Fruit		Resanding Bog		Weeding Bog		Other Work	
	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre	Total	Per Acre
Barnstable	166	.047	3,651	1.04	1,443	0.41	767	0.22	629	0.18	452	0.13
Bristol	35	.075	730	1.57	117	.25	105	.23	87	.19	33	.07
Dukes	1	.016	37	.60	11	18	23	.37	8	.13	1	.02
Essex	0		5	.36	5	.36	0		2	.14	0	
Middlesex	6	.047	104	.81	33	.26	35	.27	43	.34	11	.09
Nantucket	4	.013	141	.46	49	.16	20	.07	12	.04	14	.05
Norfolk	4	.054	59	.80	28	.38	8	.11	10	.14	9	.12
Plymouth	343	.038	10,835	1.19	2,862	.31	2,410	.27	2,023	.22	968	.11
Worcester	1	.143	8	1.14	0		5	.71	1	.14	1	.14
STATE TOTAL	560	.041	15,570	1.14	4,548	0.33	3,373	0.25	2,815	0.21	1,489	0.11

* Workers at packing houses of New England Cranberry Sales Company included. Fourteen year-round and ninety temporary employees at the local cranberry canning plants not included.

APPENDIX

TABLE 16. — CLASSIFICATION OF CRANBERRY BOG ACREAGE ACCORDING TO FLOWAGE PROTECTION IN 1934

County and Town	Dry Bog	Winter Flowage only	Winter and one Spring Flowage	Winter and two Spring Flowages	Full Flowage	Total Acres
BARNSTABLE COUNTY:						
Barnstable	34.8	91.3	115.0	39.5	203.0	483.6
Bourne	7.4	96.2	5.0	51.0	11.0	170.6
Brewster	21.8	197.3	39.5	.2	112.2	371.0
Chatham	11.0	87.7	19.7	1.0	88.8	208.2
Dennis	48.1	173.9	29.2	.8	45.4	297.4
Eastham	17.6	33.0				50.6
Falmouth		94.8	64.0	6.0	62.8	227.6
Harwich	46.7	171.8	82.3	7.0	285.0	592.8
Mashpee	36.9	45.5	47.0		158.5	287.9
Orleans	10.5	87.7	7.5	3.0	33.8	142.5
Provincetown	54.5	6.0				60.5
Sandwich	16.5	109.2	30.5	8.5	41.2	205.9
Truro	9.0	12.5			1.0	22.5
Wellfleet	3.0	13.1				16.1
Yarmouth	12.2	175.0	135.3		40.3	362.8
TOTAL	330.0	1,395.0	575.0	117.0	1,083.0	3,500.0
BRISTOL COUNTY:						
Acushnet					5.0	5.0
Berkley					5.0	5.0
Easton			2.5		45.0	47.5
Freetown		59.0	7.0	4.5	139.0	209.5
Norton					90.0	90.0
Raynham	1.0		3.0		7.0	11.0
Taunton	1.0	20.0	2.5	3.5	69.0	96.0
TOTAL	2.0	79.0	15.0	8.0	360.0	464.0
DUKES COUNTY:						
Chilmark		10.0				10.0
Edgartown		3.0				3.0
Gayhead	10.0	5.0				15.0
Tisbury	2.0	15.5	12.0			29.5
West Tisbury		4.5				4.5
TOTAL	12.0	38.0	12.0			62.0
ESSEX COUNTY:						
Groveland		2.0				2.0
Saugus					12.0	12.0
TOTAL		2.0			12.0	14.0
MIDDLESEX COUNTY:						
Billerica					15.0	15.0
Carlisle					37.0	37.0
Chelmsford		1.0			2.2	3.2
Holliston		12.0			51.8	63.8
Wilmington	1.0				8.0	9.0
TOTAL	1.0	13.0			114.0	128.0
NANTUCKET COUNTY:						
Nantucket	8.0	31.0	15.0	225.0	25.0	304.0
TOTAL	8.0	31.0	15.0	225.0	25.0	304.0
NORFOLK COUNTY:						
Foxboro					7.5	7.5
Sharon			15.0		15.5	30.5
Stoughton				9.0	10.0	19.0
Walpole			11.0	6.0		17.0
TOTAL			26.0	15.0	33.0	74.0

Table 16. — Classification of Cranberry Bog Acreage According to Flowage Protection in 1934 — Continued

County and Town	Dry Bog	Winter Flowage only	Winter and one Spring Flowage	Winter and two Spring Flowages	Full Flowage	Total Acres
PLYMOUTH COUNTY:						
Carver	69.5	513.3	483.5	281.6	1,553.1	2,901.0
Duxbury	12.5	53.4	21.8	57.5	246.2	391.4
Halifax	3.0	5.0			249.0	257.0
Hanover		9.0		15.0		24.0
Hanson	12.8	34.5			122.0	169.3
Kingston	10.5	38.3	44.5	11.5	52.0	156.8
Lakeville		40.7			115.5	156.2
Marion		25.5	21.0		49.0	95.5
Marshfield	5.5	170.2				175.7
Mattapoisett		2.5			30.5	33.0
Middleboro	18.8	268.0	.8	24.2	252.1	563.9
Pembroke	1.0	62.5	64.3		242.6	370.4
Plymouth	149.8	216.2	127.0	67.5	725.2	1,285.7
Plympton	1.8	11.5		12.0	159.2	184.5
Rochester	21.2	105.4	61.1	133.4	396.0	717.1
Scituate	1.0	3.2			19.0	23.2
Wareham	56.6	224.8	285.0	260.3	759.6	1,586.3
TOTAL	364.0	1,784.0	1,109.0	863.0	4,971.0	9,091.0
WORCESTER COUNTY:						
Ashburnham					2.0	2.0
Upton					5.0	5.0
TOTAL					7.0	7.0
MASSACHUSETTS TOTAL	717.0	3,342.0	1,752.0	1,228.0	6,605.0	13,644.0
RHODE ISLAND:						
Kent			2.0		68.0	70.0
TOTAL			2.0		68.0	70.0
CONNECTICUT:						
New London					12.2	12.2
TOTAL					12.2	12.2

TABLE 17. — CRANBERRY PRODUCTION — 1867–1900[*]
(IN BARRELS)

Year	New England[†]	New Jersey	The West	New York	United States Total
1867	12,000	35,000	15,500		62,500
1868	Crop ½ of average yield		3,220		
1869	11,000	50,000	14,585		75,585
1870					
1871					
1872	13,333	33,333	45,000		91,666
1873	35,000	36,666	20,000		91,666
1874	35,000	30,000	16,667	1,666	83,333
1875	25,000	36,667	13,333	1,666	76,666
1876	21,667	30,000	13,333	1,000	66,000
1877	54,743	50,700	26,500	1,666	133,609
1878	41,666	20,000	35,923	1,000	98,589
1879	65,000	30,000	25,000	1,000	111,000
1880	82,500	42,900	37,810	1,000	164,210
1881	51,942	52,338	47,729	1,666	153,675
1882	63,888	26,169	16,667	666	107,390
1883	47,321	39,508	45,169		131,998
1884	43,528	41,549	8,261		93,338
1885	93,626	66,042	88,144		247,812
1886	91,600	78,085	10,465		180,150
1887	102,521	54,596	46,891		204,008
1888	86,667	75,000	33,333		195,000
1889	67,167	45,000	20,583		132,750
1890	125,000	66,666	75,000		266,666
1891	160,000	83,333	10,000		253,333
1892	125,000	53,333	21,667		200,000
1893	191,667	108,333	33,333		333,333
1894	61,666	66,667	8,333		136,666
1895	140,000	66,667	3,333		210,000
1896	200,000	66,666	10,000		276,666
1897	133,333	83,333	16,667		233,333
1898	141,666	100,000	25,000		266,666
1899	208,333	83,333	36,666		328,333
1900	166,667	100,000	18,333		285,000

[*] These figures were taken from Proceedings of the Seventeenth and Twentieth Annual Conventions of the American Cranberry Growers' Association, the 1901 report of the New Jersey State Board of Agriculture and the 1869 report of the United States Department of Agriculture (see page 16).

[†] Figures for New England include New York where it is not given separately.

TABLE 18. — CRANBERRY PRODUCTION — 1901–1935*
(IN BARRELS)

Year	Massachusetts	New Jersey	Wisconsin	Pacific Coast	Indicated United States Total
1901	264,000	105,000	40,000		409,000
1902	238,000	30,000	46,000		314,000
1903	226,000	168,000	18,000		412,000
1904	281,000	83,000	21,000		385,000
1905	165,000	88,000	18,000		271,000
1906	264,000	103,000	45,000		412,000
1907	310,000	121,000	21,000		452,000
1908	257,000	75,000	12,000		344,000
1909	402,000	165,000	30,000		597,000
1910	312,000	241,000	16,000		569,000
1911	298,000	143,000	30,000		471,000
1912	354,000	112,000	45,000		511,000
1913	367,000	100,700	30,000		497,700
1914	471,000	210,000	32,000		713,000
1915	257,000	184,000	36,000		477,000
1916	364,000	217,000	33,000		614,000
1917	137,000	129,000	30,000		296,000
1918	218,000	126,100	29,900		374,000
1919	395,000	143,000	46,000		584,000
1920	309,000	133,000	36,000		478,000
1921	208,000	160,000	29,000		397,000
1922	337,000	200,000	55,000		592,000
1923	451,000	205,000	37,000		693,000
1924	339,000	215,000	42,000	14,000	610,000
1925	447,000	115,000	25,000	22,000	609,000
1926	438,000	210,000	80,000	23,600	751,600
1927	385,000	75,000	24,000	27,000	511,000
1928	348,000	138,000	50,000	28,000	564,000
1929	421,000	90,000	42,000	16,800	569,800
1930	395,000	144,000	40,000	6,480	585,480
1931	460,000	142,000	45,000	14,000	661,000
1932	415,000	80,000	80,000	9,836	584,836
1933	506,000	142,000	47,000	8,700	703,700
1934	290,000	70,000	59,000	24,300	443,300
1935†	332,000	85,000	81,000	21,500	519,500

---

* Revised estimates of cranberry production in Massachusetts based on reported shipments and other items of disposal. New Jersey and Wisconsin estimates for period 1901 to 1913 are shipments as reported by the American Cranberry Exchange. New Jersey, Wisconsin, and Pacific Coast estimates 1914 to date are unrevised official estimates of the United States Department of Agriculture.

† Preliminary estimate.

TABLE 19. — CRANBERRY PRODUCTION IN MASSACHUSETTS, BY VARIETIES AND COUNTIES, IN 1931, 1932, AND 1933, AS REPORTED IN THE 1934 SURVEY.

County	Total Bog Acreage 1933	Yield per Acre in Barrels*			Production — in Barrels		
		1931	1932	1933	1931	1932	1933
			Early Black				
Barnstable	1,832.9	28.4	26.3	32.5	52,085	48,288	59,615
Bristol	217.4	30.2	31.1	36.6	6,567	6,751	7,964
Dukes	9.7	15.9	26.6	26.3	154	258	255
Essex	2.0	7.0	17.0	14.0	14	34	28
Middlesex	23.0	55.4	42.3	50.5	1,275	973	1,161
Nantucket	89.0	31.5	14.8	28.7	2,805	1,321	2,553
Norfolk	23.5	3.8	1.7	4.5	90	40	105
Plymouth	4,436.9	42.5	34.9	48.0	188,421	154,649	212,826
Worcester	2.0						
STATE TOTAL	6,636.4	37.9	32.0	42.9	251,411	212,314	284,507
			Howes				
Barnstable	906.7	21.8	22.5	22.4	19,809	20,365	20,282
Bristol	217.9	33.9	34.4	40.8	7,391	7,497	8,880
Dukes	5.8	11.9	7.9	10.5	69	46	61
Essex	8.0	8.4	25.0	20.9	67	200	167
Middlesex	54.7	24.4	24.4	26.3	1,332	1,335	1,440
Nantucket	200.8	14.7	13.7	15.1	2,949	2,742	3,040
Norfolk	30.0	14.1	8.1	15.6	424	242	468
Plymouth	3,947.5	34.6	33.1	36.5	136,495	130,847	144,079
Worcester	2.0	35.0	25.0	23.5	70	50	47
STATE TOTAL	5,373.4	31.4	30.4	33.2	168,606	163,324	178,464
			Other Varieties				
Barnstable	760.4	18.0	16.3	18.4	13,725	12,425	14,014
Bristol	28.7	24.1	21.5	36.0	693	618	1,034
Dukes	46.5	9.2	12.7	3.0	428	592	140
Essex	4.0	6.0	16.5	13.8	24	66	55
Middlesex	50.3	29.9	18.0	15.4	1,503	905	773
Nantucket	14.2	13.7	15.8	10.4	194	225	148
Norfolk	20.5	30.3	26.6	28.3	622	545	581
Plymouth	706.6	30.5	33.0	36.5	21,581	23,287	25,773
Worcester	3.0	100.0	50.0	50.0	300	150	150
STATE TOTAL	1,634.2	23.9	23.8	26.1	39,070	38,813	42,668
			TOTAL — All Varieties				
Barnstable	3,500.0	24.5	23.2	26.8	85,619	81,078	93,911
Bristol	464.0	31.6	32.0	38.5	14,651	14,866	17,878
Dukes	62.0	10.5	14.5	7.4	651	896	456
Essex	14.0	7.5	21.4	17.9	105	300	250
Middlesex	128.0	32.1	25.1	26.4	4,110	3,213	3,374
Nantucket	304.0	19.6	14.1	18.9	5,948	4,288	5,741
Norfolk	74.0	15.4	11.2	15.6	1,136	827	1,154
Plymouth	9,091.0	38.1	34.0	42.1	346,497	308,783	382,678
Worcester	7.0	52.9	28.6	28.1	370	200	197
STATE TOTAL	13,644.0	33.6	30.4	37.1	459,087	414,451	505,639

* Derived from production and total bog acreage.

TABLE 20. — RECORDED MASSACHUSETTS CRANBERRY SHIPMENTS BY COUNTIES (IN BARRELS)
1909–1935*

(Reported by New York, New Haven and Hartford Railroad Company)

Year	Barnstable	Bristol	Middlesex	Norfolk	Plymouth	Other Counties	Total
1909	116,939	5,482		877	250,324		373,622
1910	80,909	4,618		523	200,996		287,046
1911	93,464	5,073		805	173,798		273,140
1912	121,319	4,842	8	756	200,994	117	328,036
1913	79,997	7,507		349	253,382		341,235
1914	127,283	16,844		701	290,468		435,296
1915	57,676	9,277	661	721	166,867	30	235,232
1916	107,333	8,994	615	473	220,340		337,755.
1917	29,459	4,718	50	14	82,676		116,917
1918	62,255	6,266		683	125,303		194,507
1919	90,319	6,953		270	267,864		365,406
1920	68,051	6,868		356	199,467		274,742
1921	38,173	3,397		225	140,374		182,169
1922	74,508	8,609		310	209,372		292,799
1923	96,282	7,395		286	274,005		377,968
1924	61,505	11,410		458	202,691		276,064
1925	90,369	11,402	1,279	449	274,847		378,346
1926	50,860	11,714	1,115	229	301,194		365,112
1927	54,992	12,022	2,796	297	251,839		321,946
1928	55,288	9,522	225	460	199,801		265,296
1929	54,319	5,721	1,321	423	274,873		336,657
1930	46,348	10,394	1,690	445	254,090	3	312,970
1931	59,812	10,772	1,897	744	289,387		362,612
1932	56,179	12,304	2,334	230	233,279		304,326
1933	65,450	15,678	2,035	769	275,042		358,974
1934	28,198	10,532	1,351		172,812		212,893
1935	26,952	12,219	2,428	240	175,483	1,406	218,728

*Includes C.L. and L.C.L. shipments.

Table 21. — Wholesale Cranberry Prices — 1863–1900*
(Price per Barrel)

Crop Year	September 1	October 1	January 1	February 1	May 1	Average
1863		$12.00		$15.00		
1864		11.00		14.00		
1865		14.00		15.00		
1866		15.00		16.00		
1867		16.00		24.00		
1868		28.00		32.00		
1869		10.00		24.00		
1870	$10.50–$12.00				$ 3.00–$ 3.75	
1871	9.75– 12.00				13.50– 16.50	
1872	9.75– 12.00				4.50– 6.00	
1873	7.50– 9.00				11.25– 15.00	
1874	8.25– 9.00				5.25– 6.00	
1875	6.00– 8.25				14.25– 15 00	
1876	9.75– 10.50				6 00–Nom'l	
1877	6.00– 7.50				12.00–	
1878	6.00– 6.75				6.75– 7.50	
1879	5.25– 6.00				15.00– 18.00	
1880	4.50– 6.00				1.50– 3.00	
1881	4.50– 6.00		$10.50–$12.00		6.00– 9.00	
1882		$8.25–$9.00	12.00– 13.50		6.00 10.50	
1883		8.25– 9.00	10.50– 11.25		15.75– 16.50	
1884		8.25– 9.00	13.50– 14.25		7.50– 8.25	
1885		4.50– 5.10	3.60– 4.20		1.50– 2.25	
1886		3.75– 4.50	7.50– 8.25		11.25– 12.00	
1887		5.25– 6.00	8.25– 9.00		8.25– 9.00	
1888	$6.56	$7.26	$5.97	6.36		$6.58
1889	5.72	6.54	8.94	10.00		6.61
1890	7.19	6.81	10.50	10.08		7.71
1891	6.08	5.14	5.38	5.56		5.51
1892	5.78	5.18	7.50	7.50		5.78
1893	4.49	3.70	4.92	5.62		4.26
1894	6.80	7.04	8.74	10.50		7.53
1895	5.20	5.76	8.25	7.44		6.17
1896	4.26	3.48	2.68	2.50		3.35
1897	4.26	4.46	5.69	7.11		5.02
1898	4.46	4.29	5.71	6.08	$8.50	5.19
1899	4.02	3.88	5.18	6.31		4.26
1900	4.99	4.75	7.69	7.00		6.17

* Prices for the years 1863 to 1869, inclusive, are average prices reported at Philadelphia. For the years 1870 to 1887, inclusive, they are the opening and closing prices at New York, taken from the annual reports of the American Cranberry Growers' Association. For the years 1888 to 1900, inclusive, they are prices at Boston, taken from the C. M. Barrows Market Reports.

Publication of this Document Approved by Commission on Administration and Finance
3500 — 8-'36. No. 8411.

14b
3
333

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 333 JULY 1936

A Study in Soil Nitrogen

By F.W. Morse

No plant food element has received and deserved more consideration than nitrogen. The part that Massachusetts Agricultural Experiment Station has contributed in an attempt to assign to it a correct place in economic plant production is here further recorded.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

A STUDY IN SOIL NITROGEN

By F. W. Morse, Research Professor of Chemistry[1]

INTRODUCTION

The history of "Field A" of the Massachusetts Agricultural Experiment Station has been recorded continuously since 1882, when the field was regarded as "run-out grassland." A review of its history up to 1921 has been published in Bulletin 290 (1932). The construction of the Goessmann Chemistry Laboratory in 1922 necessitated abandoning Plots 0, 1, 2, 3, and 4. The numbers of the remaining plots — 5, 6, 7, 8, 9, and 10 — were retained in order to avoid confusion.

Longfellow yellow flint corn was grown in 1922 and 1923 with the fertilizer plan described in Bulletin 290. The data of 1922 were the basis for retaining the plots mentioned. The crop of 1923 was in preparation for the new experiment, which was to begin with clovers and grasses seeded in the corn.

Plots 7 and 9 were the key plots in the new study, because they had not received any nitrogen in fertilizers since sometime before 1882. Few analyses had been made of crops actually grown on these plots, but many analyses of the same kinds of crops were at hand. From these data it was calculated that the crops taken from these plots in forty-one harvests, 1883 to 1923 inclusive, had contained nitrogen equivalent to an average of 2,700 pounds per acre. The leguminous crops taken from the plots during this period possibly contained 1,270 pounds, leaving 1,430 pounds in the nonleguminous series.

The object of the new experiment was to measure the nitrogen recovered in the continuous production of nonleguminous crops and in rotations in which leguminous crops alternated with nonleguminous crops.

PLAN OF EXPERIMENT

Each plot in the original "Field A" was 8 rods long by 2 rods wide and contained $\frac{1}{10}$ acre. For this experiment every plot was divided into four subplots, 2 rods square and containing $\frac{1}{40}$ acre each. This permitted duplicate areas of legumes and of nonlegumes on each numbered plot.

The fertilizers differed but little from those formerly used. All plots received superphosphate and sulfate of potash equivalent to 80 pounds phosphoric acid and 125 pounds actual potash per acre. Plot 5 received nitrate of soda; Plot 8, sulfate of ammonia; and Plot 10, dry ground fish — in each case an amount furnishing 45 pounds nitrogen per acre. Nitrogen was withheld every other year in order to measure any residual nitrogen from the fertilizers. Plots 6, 7, and 9 did not have nitrogen fertilizers.

Changes from the previous fertilizer plan were the substitution of sulfate of potash for muriate on all plots, and of nitrate of soda for sulfate of ammonia on Plot 5, and the withholding of nitrogen from Plot 6 which heretofore had received sulfate of ammonia like Plot 8.

Table 1 shows the arrangement of the plots and subplots.

---

[1] This publication was prepared after the author's retirement from active service in December 1935.

TABLE 1. — ARRANGEMENT OF PLOTS AND SUBPLOTS

Legume	Nonlegume	Legume	Nonlegume
	Organic nitrogen since 1882		
10 LW	10 NLW	10 LE	10 NLE
	No nitrogen since 1882		
9 LW	9 NLW	9 LE	9 NLE
	Sulfate of ammonia since 1882		
8 LW	8 NLW	8 LE	8 NLE
	No nitrogen since 1882		
7 LW	7 NLW	7 LE	7 NLE
	No nitrogen since 1923		
6 LW	6 NLW	6 LE	6 NLE
	Nitrate of soda since 1923		
5 LW	5 NLW	5 LE	5 NLE

The original plots, 5, 6, 7, 8, 9, and 10, are 8 rods long and 2 rods wide, and contain 1/10 acre.

The sections LW, NLW, LE, and NLE of each plot are 2 rods square and contain 1/40 acre.

The crops[2] chosen were annuals, with the exception of grasses and clovers. Summer crops were preferred because soil organisms are more active in warm soil. Seedings were planned for dates that would permit growth during June, July, and August and harvesting at stages of growth before ripened seeds could scatter.

The crops on each subplot were sampled and weighed immediately after being cut, except in 1932 when a sudden shower obliged several subplots to lie for twenty-four hours. This part of the work has been performed by the writer with few exceptions. Samples were taken at random from different parts of a subplot while the crop lay flat, and were weighed when gathered. They were allowed to dry under shelter until it was convenient to analyze them. The air-dry samples were then weighed and run through a feed cutter. Subsamples were taken by quartering and prepared for determinations of dry matter and nitrogen.[3]

---

[2] In planning the system of crops, important suggestions were received from Professor A. B. Beaumont and Director S. B. Haskell.

[3] All determinations of dry matter and nitrogen have been made in the Feed Control Laboratory under the supervision of Mr. P. H. Smith, whose kindly cooperation is highly appreciated.

YEARLY NOTES AND YIELDS

Detailed field records for each year seem unnecessary. Certain outstanding facts are briefly mentioned.[4]

1923. As previously stated, corn was grown and at the last hoeing each plot was divided crosswise into four subplots of 1/40 acre each. Two alternate subplots were seeded with a mixture of red and alsike clovers and two with a mixture of timothy and red top grasses. All plots were in excellent condition when winter came.

1924. Fertilizers according to the new plan were applied as a top-dressing in the spring. Broadcasting the seed in the corn resulted in overlapping of clovers and grasses, so that considerable labor was required to remove the clover plants from the grass subplots without nitrogen. Grasses were not removed from the clover subplots, and timothy plants amid the clover were larger than on the grass areas. Following the July cutting, the season was relatively dry. A light crop of rowen was cut from the clover subplots in September, but none was taken from the grasses.

1925. Clover had disappeared from the legume subplots and grasses appeared to constitute the sod on all areas. The field was plowed late in April, and prepared for a crop of Golden Bantam sweet corn, which was grown on all subplots as the nonlegume in both rotation and continuous nonlegume series. As the season advanced, the corn following clover was larger than that following grasses. The corn was harvested when it began to show roasting ears. Immediately after the removal of the corn, the field was prepared for a crop of winter vetch on the legume and winter rye on the nonlegume subplots.

1926. Rye passed through the winter in excellent condition, but much of the vetch died. Consequently the field was plowed and prepared for soybeans as the legume and Japanese barnyard millet as the nonlegume. Nitrogen was applied to Plots 5, 8, and 10. Millet showed much larger growth with nitrogen than without it. Soybeans appeared to respond to it a little. Cuttings were made when heads had formed on the millet and pods on the soybeans.

1927. Golden Bantam sweet corn was again selected for nonlegume on all subplots. The field was plowed and repeatedly harrowed before the corn was planted in the first week of July. Decomposition of the stubble and roots of the previous crops would be progressing actively by this date. Plants following millet were continuously superior to those following soybeans. Frosts were late and the corn was harvested the first week in October unharmed, with many ears at the roasting stage.

1928. Nitrogen was applied to Plots 5, 8, and 10. In the spring red and alsike clovers were sown on the legume and timothy and red top on the nonlegume subplots, without a nurse crop. Weeds overtopped both clovers and grasses and were included in the harvested crops, which were cut when in bloom. A good growth of clovers and grasses followed and was left uncut as a protection against winterkilling.

1929. All plots were in excellent condition in the spring and free from weeds. Fertilizers were applied as a top-dressing, and nitrogen was omitted. Volunteer plants of white clover appeared among the grasses and were removed from the subplots of 6, 7, and 9. Crops were cut early in July. Scattered timothy plants had grown amid the clover and on the plots without nitrogen fertilizer were found to be from 7 to 10 inches taller than the timothy plants in the midst of grasses. Dry weather followed the removal of the crops and no second crop was secured. The field was plowed in September, preventing any additional development of clovers amid the grasses.

1930. Japanese millet was grown on all plots and nitrogen was applied to Plots 5, 8, and 10. As the crop developed, the millet with nitrogen was superior to that without it; millet following grasses appeared nearly equal to that following clover. Heads were beginning to show when, on July 22 and 24, very severe thunder showers occurred. The crop then showed the unequal effects which weather may sometimes have in field experiments. Millet on the nonlegume subplots without nitrogen remained erect and continued its growth unhindered. On the plots with nitrogen the millet was completely flattened and never regained its erect form. The legume subplots without nitrogen were partially flattened and recovered somewhat better than those with nitrogen. Consequently the millet without nitrogen was more nearly equal to the crop with it than would probably have been the case under normal weather conditions.

---

[4] Mr. E. F. Gaskill and Mr. C. W. Everson have had charge of the field work and have given full cooperation throughout the investigation.

1931. Oats and field peas were sown on the legume and oats alone on the nonlegume subplots. An early crop was selected to ascertain how it responded to residual nitrogen and no nitrogen. Oats appeared to be uniform in height throughout the field. The field peas made the growth on the legume subplots appear to be denser than on the areas with oats alone. The crops were harvested before seeds were filled in both oats and peas. After these crops were removed a growth of barnyard grass covered the field and was most abundant on the nonlegume areas. White clover also showed on these areas and the field was plowed to prevent its further development.

1932. Soybeans were sown on the legume and Hungarian millet on the nonlegume subplots, and nitrogen was applied to Plots 5, 8, and 10. Both crops showed the effect of nitrogen by larger plants and darker green foliage. Weeds were prominent on the nitrogen plots but were found to constitute an insignificant part of the crop. The crops were cut when the millet was in bloom and before the soybeans formed pods. A cover crop of mixed barley, buckwheat, and oats followed the removal of the soybeans and millet. This cover crop was killed by frost but served to protect the surface from winds.

1933. It was planned to use alfalfa as a perennial legume and accompany it with annual nonlegumes. Barley was selected to accompany the alfalfa this year. Since alfalfa in its earliest stages responds to nitrogen fertilizer, Plots 5, 8, and 10 received their usual allotment. Seeding was deferred until July and the field was repeatedly harrowed to destroy weeds. Both alfalfa and barley developed normally. It was planned to leave the alfalfa uncut for better winter protection; consequently the barley was left unharvested. On October 10 the barley was fully headed with kernels partly filled. The nitrogen plots showed a height of 36 to 40 inches, while without nitrogen the height was 28 to 38 inches. Alfalfa with nitrogen was from 8 to 11 inches tall, and without nitrogen, 5 to 10 inches. A heavy frost on October 25 prostrated the barley on the nitrogen plots, but the plants without nitrogen remained erect until the next severe frost.

1934. The alfalfa was nearly all winterkilled; therefore, the whole field was plowed and a liberal amount of organic matter was turned under, especially on the nonlegume subplots. Hungarian millet was sown on all subplots on June 9. Nitrogen was omitted. The appearance of the field was quite uniform as the crop advanced; but when fully headed, Plot 10 was definitely taller than any other plot. The west tier of nonlegume subplots bore shorter plants than the legume subplots; but the east tier of nonlegume subplots bore taller plants than the adjacent legume tier.

1935. Nitrogen was applied to Plots 5, 8, and 10. Oats and field peas were sown on the legume subplots, while oats alone were used as the nonlegume crop. These crops were chosen for comparison with like crops grown in 1931 without applied nitrogen. Oats on the nonlegume subplots showed a marked effect from nitrogen fertilizers. Oats and peas on the legume subplots were a little superior on the nitrogen plots; but on those without nitrogen the oat plants amid the peas were stouter and darker in color than the oats alone, and much like the oats with nitrogen fertilizer. The crops were harvested as soon as pods formed on the peas and the oats were fully headed but not filled.

The succession of crops and application and omission of nitrogen are shown in Tables 2 and 3. Yields of dry matter and nitrogen have been averaged for the duplicate subplots on each plot, and are expressed in pounds per acre, The subplots are grouped in their respective legume and nonlegume series, together with the corresponding crops.

TABLE 2. — YIELDS OF DRY MATTER AND NITROGEN — POUNDS PER ACRE.

WITH NITROGEN

Year	Legume Subplots			Nonlegume Subplots		
	Crop	Dry Matter	Nitrogen	Crop	Dry Matter	Nitrogen
		Plot 5. Nitrate of Soda				
1924	*Clover	2,660	60.2	*Grass	4,280	32.2
1924	Clover rowen	1,380	42.0	No rowen	....	....
1925	Sweet corn	2,760	49.2	Sweet corn	2,080	29.8
1926	*Soybeans	3,700	77.6	*Japanese millet	8,600	86.0
1927	Sweet corn	1,980	34.0	Sweet corn	2,320	41.4
1928	*Clover	2,940	42.4	*Grass	3,840	46.4
1929	Clover	3,120	68.2	Grass	1,780	15.4
1930	*Japanese millet	7,360	88.0	*Japanese millet	7,500	79.4
1931	Oats and peas	2,400	40.8	Oats	1,680	23.2
1932	*Soybeans	3,980	93.2	*Hungarian millet	5,680	54.6
1933	*Alfalfa	Plowed under		*Barley	Plowed under	
1934	Hungarian millet	3,960	34.2	Hungarian millet	3,540	33.0
1935	*Oats and peas	3,800	73.6	*Oats	4,600	63.2
	Total	40,040	703.4	Total	45,900	504.6
		Plot 8. Sulfate of Ammonia				
1924	*Clover	2,360	57.2	*Grass	4,260	27.8
1924	Clover rowen	1,400	40.2	No rowen	....	....
1925	Sweet corn	3,520	57.2	Sweet corn	2,160	30.0
1926	*Soybeans	3,240	75.8	*Japanese millet	9,540	73.8
1927	Sweet corn	2,200	37.4	Sweet corn	2,460	43.6
1928	*Clover	2,840	39.2	*Grass	3,420	32.4
1929	Clover	3,980	91.0	Grass	1,680	18.2
1930	*Japanese millet	6,780	76.8	*Japanese millet	7,040	70.8
1931	Oats and peas	2,600	47.8	Oats	2,000	24.0
1932	*Soybeans	4,460	105.8	*Hungarian millet	4,900	49.8
1933	*Alfalfa	Plowed under		*Barley	Plowed under	
1934	Hungarian millet	3,840	34.0	Hungarian millet	4,040	34.8
1935	*Oats and peas	3,600	62.0	*Oats	4,320	45.2
	Total	40,820	724.4	Total	45,820	450.4
		Plot 10. Dry Ground Fish				
1924	*Clover	2,380	57.8	*Grass	3,040	22.0
1924	Clover rowen	1,540	44.0	No rowen	....	....
1925	Sweet corn	3,980	68.6	Sweet corn	2,800	40.4
1926	*Soybeans	4,080	110.0	*Japanese millet	9,420	80.4
1927	Sweet corn	2,880	50.6	Sweet corn	2,780	50.4
1928	*Clover	3,080	39.2	*Grass	4,200	40.8
1929	Clover	3,780	83.8	Grass	2,320	23.8
1930	*Japanese millet	6,640	95.2	*Japanese millet	6,560	89.2
1931	Oats and peas	2,700	50.8	Oats	2,500	32 2
1932	*Soybeans	4,660	98.4	*Hungarian millet	5,580	52.6
1933	*Alfalfa	Plowed under		*Barley	Plowed under	
1934	Hungarian millet	4,300	38.2	Hungarian millet	4,620	41.6
1935	*Oats and peas	3,880	85.6	*Oats	4,480	52.0
	Total	43,900	822.2	Total	48,300	525.4

*Nitrogen applied.

TABLE 3. — YIELDS OF DRY MATTER AND NITROGEN — POUNDS PER ACRE.

WITHOUT NITROGEN

Year	Legume Subplots			Nonlegume Subplots		
	Crop	Dry Matter	Nitrogen	Crop	Dry Matter	Nitrogen
		Plot 6. No Nitrogen				
1924	Clover	2,800	73.4	Grass	2,120	15.2
1924	Clover rowen	1,260	39.4	No rowen	....	....
1925	Sweet corn	3,120	59.2	Sweet corn	1,860	27.2
1926	Soybeans	3,660	73.6	Japanese millet	10,220	83.4
1927	Sweet corn	2,140	37.8	Sweet corn	2,500	43.8
1928	Clover	2,480	36.2	Grass	3,300	30.6
1929	Clover	4,040	90.6	Grass	1,400	12.8
1930	Japanese millet	7,480	91.0	Japanese millet	6,840	66.0
1931	Oats and peas	2,340	42.4	Oats	1,940	25.0
1932	Soybeans	3,660	96.8	Hungarian millet	3,260	26.0
1933	Alfalfa	Plowed under		Barley	Plowed under	
1934	Hungarian millet	3,680	31.2	Hungarian millet	3,760	32.4
1935	Oats and peas	3,660	64.8	Oats	2,340	23.0
	Total	40,320	736.4	Total	39,540	385.4
		Plot 7. No Nitrogen				
1924	Clover	1,900	50.0	Grass	890	7.4
1924	Clover rowen	1,440	43.2	No rowen	....	....
1925	Sweet corn	3,240	53.0	Sweet corn	2,020	28.2
1926	Soybeans	3,300	77.0	Japanese millet	4,840	36.0
1927	Sweet corn	2,380	39.2	Sweet corn	2,420	41.0
1928	Clover	2,820	42.2	Grass	3,320	29.6
1929	Clover	3,740	90.6	Grass	1,100	10.8
1930	Japanese millet	5,520	65.6	Japanese millet	6,860	77.4
1931	Oats and peas	2,520	44.8	Oats	2,080	27.0
1932	Soybeans	4,080	107.2	Hungarian millet	3,360	26.2
1933	Alfalfa	Plowed under		Barley	Plowed under	
1934	Hungarian millet	4,180	37.6	Hungarian millet	3,760	32.0
1935	Oats and peas	3,520	65.0	Oats	2,240	25.0
	Total	38,640	715.4	Total	32,890	340.6
		Plot 9. No Nitrogen				
1924	Clover	2,580	63.8	Grass	1,080	10.0
1924	Clover rowen	1,480	44.6	No rowen	....	....
1925	Sweet corn	3,880	65.6	Sweet corn	2,220	28.8
1926	Soybeans	3,500	87.6	Japanese millet	4,680	30.8
1927	Sweet corn	2,560	40.6	Sweet corn	2,840	47.8
1928	Clover	3,160	44.8	Grass	3,420	30.4
1929	Clover	4,080	92.4	Grass	1,360	13.2
1930	Japanese millet	5,560	71.2	Japanese millet	6,740	64.4
1931	Oats and peas	2,680	46.8	Oats	2,140	26.8
1932	Soybeans	4,340	110.2	Hungarian millet	3,800	32.2
1933	Alfalfa	Plowed under		Barley	Plowed under	
1934	Hungarian millet	4,440	39.0	Hungarian millet	4,040	33.8
1935	Oats and peas	3,220	66.8	Oats	2,340	26.2
	Total	41,480	773.4	Total	34,660	344.4

DISCUSSION OF TABLES

Some individuality was shown by the plots without nitrogen. Plot 6 was strikingly superior to Plots 7 and 9 in 1924 with both grasses and clovers. This superiority was shown by the west half of the plot, while the east half was practically like the same areas on the other plots. Plot 6 had been heavily limed in 1923 to overcome the ill effect of continuous use of sulfate of ammonia. The crop of 1924 was its first without nitrogen, and residual nitrogen appeared to be the cause of its superiority over the plots which had been continuously without nitrogen fertilizers in previous years. Plot 6 was again superior in 1926, when its crop of Japanese millet was larger than the crops of the other two added together and its soybean crop was slightly superior to the other two. The sweet-corn crops of 1925 and 1927 were inferior to the like crops on Plots 7 and 9.

After 1927, the crops on legume and nonlegume subplots were reasonably comparable for the three plots, no one of which was continuously in the lead. Residual effects of the former nitrogen applications on Plot 6 appeared to be completely eliminated. The summary of seven harvests, 1928 to 1935 inclusive, follows:

Plot	Legume Supblots Pounds per Acre	Nonlegume Subplots Pounds per Acre
6	27,340	22,840
7	26,380	22,720
9	27,480	23,840

The effect of a crop on its succeeding crop is of interest as shown by the yields in these tables. In 1925 sweet corn following clover was much superior to the like crop following the grasses; but in 1927 the sweet corn was larger following Japanese millet than following soybeans. Although soybeans were themselves able to use the nitrogen supplied by microorganisms, their stubble and roots were of little benefit to succeeding crops.

The two successive crops of clovers and grasses in 1928 and 1929 were a paradox. The first-year crops included many weeds; and perhaps for this reason, the grass subplots on all plots bore larger yields than the clover subplots. The second-year crops, which were practically free from weeds, were much larger on all clover subplots. The Japanese millet which followed the clovers and grasses in 1930 was so much affected by the weather that yields varied under like conditions.

In 1931, in the absence of nitrogen fertilizers, oats and peas excelled oats alone; but in 1935 applications of nitrogen caused oats to be superior to oats and peas. On plots without nitrogen, oats were a second time inferior to oats and peas.

In 1932 Hungarian millet with applied nitrogen exceeded soybeans in yield, but without nitrogen the soybeans took the lead. In 1934, Hungarian millet followed plowed-under crops of alfalfa and barley with and without residual nitrogen. With residual nitrogen the crops were virtually equal; without, the crop on alfalfa subplots was slightly superior.

In this investigation clover was the only legume to have a striking effect on the following crop. The presence and absence of nitrogen have not caused any appreciable variation in the percentages of nitrogen in the crops when the grand averages of the series of crops are compared.

	With Nitrogen	Without Nitrogen
Legume subplots	1.80	1.85
Nonlegume subplots	1.06	1.00

COMPARISON OF NITROGEN FERTILIZERS

There are some outstanding differences between the nitrogen plots, especially on the nonlegume subplots. The three plots without nitrogen have been averaged to overcome their individuality. The plots with nitrogen have been averaged for comparison with the other group but are also tabulated individually. Tables 4 and 5 are arranged to show the legume subplots and nonlegume subplots in separate groups with fertilizer nitrogen and with residual nitrogen.

Nitrogen was applied in 7 years out of the 12 recorded, but alfalfa and barley in 1933 were left uncut and subsequently plowed under. There are, therefore, 6 harvests from nitrogen in one group and 5 harvests from residual nitrogen in the other. On the legume subplots, the applications of nitrogen were made on legumes with one exception, Japanese millet. Plot 10 with organic nitrogen in dry fish was slightly superior to the others in the total yield of dry matter, but Plot 5 with nitrate of soda was notably superior with the millet.

Of the nonlegume subplots with fertilizer nitrogen, Plot 5 was superior to the others in 1924, 1930, and 1935 and in total yield. Plot 10 was practically equal to Plot 8, which received sulfate of ammonia.

In the years with residual nitrogen, Plot 10 with its organic nitrogen residues was always superior to Plot 5, which appeared to retain no nitrate residue because it was inferior to the average production of the plots without nitrogen except with grass in 1929.

On the legume subplots, applications of nitrogen had little effect except on the nonlegume, Japanese millet. Clovers were practically unaffected, soybeans were increased 7 percent, oats and peas 8.6 percent. The crops with residual nitrogen were in the aggregate actually inferior to those without any nitrogen. The net result for the application of 315 pounds per acre of nitrogen in various forms was a total gain of 1460 pounds of dry matter and 7.5 pounds of nitrogen, due mainly to the millet.

Applications of nitrogen to the crops on the nonlegume subplots produced an increase of 9860 pounds of dry matter and 119.7 pounds of nitrogen. The residual nitrogen on Plots 8 and 10 caused an average increase for the group of 1190 pounds of dry matter and 16.7 pounds of nitrogen. The total gain for the 315 pounds per acre of applied nitrogen was 11,050 pounds of dry matter and 136.4 pounds of nitrogen. Only 43.3 percent of the applied nitrogen appeared to be recovered in the crops, 38 percent when applied and 5.3 percent with residual nitrogen.

PREVIOUS TREATMENT WITH LIME

All plots were dressed with hydrated lime in 1898 and 1905 at the rate of 2000 pounds per acre each time. The east half of each plot received hydrated lime at the rate of 5000 pounds per acre in 1909 and 4000 pounds per acre in 1913. Liming was not repeated until 1919, when Plots 5, 7, 9, and 10 received 2000 pounds per acre of ground limestone on the north half of each plot. Plot 8 received an equal dressing over the whole plot, while Plot 6 was not given any lime.

TABLE 4. — DRY MATTER AND NITROGEN TAKEN FROM LEGUME SUBPLOTS

POUNDS PER ACRE

		WITH FERTILIZER NITROGEN (Plots 5, 8, 10)					WITHOUT NITROGEN (Plots 6, 7, 9)	
Year	Crop	Dry Matter				Nitrogen Average	Dry Matter Average	Nitrogen Average
		Plot 5	Plot 8	Plot 10	Average			
1924	Clover...........	4,040	3,760	3,920	3,900	100.5	3,820	104.8
1926	Soybeans.........	3,700	3,240	4,080	3,680	87.8	3,480	79.4
1928	Clover...........	2,940	2,840	3,080	2,960	40.3	2,820	41.1
1930	Japanese millet...	7,360	6,780	6,640	6,920	86.7	6,200	75.9
1932	Soybeans.........	3,980	4,460	4,660	4,360	99.1	4,020	104.7
1935	Oats and peas.....	3,800	3,600	3,880	3,760	73.7	3,460	65.5
	Total........	25,820	24,680	26,260	25,580	488.1	23,800	471.4
	WITH RESIDUAL NITROGEN							
1925	Sweet corn.......	2,760	3,520	3,980	3,420	58.3	3,410	59.3
1927	Sweet corn.......	1,980	2,200	2,880	2,360	40.7	2,350	39.2
1929	Clover...........	3,120	3,980	3,780	3,620	81.0	3,960	91.2
1931	Oats and peas.....	2,400	2,600	2,700	2,560	46.5	2,500	44.7
1934	Hungarian millet..	3,960	3,840	4,300	4,040	35.5	4,100	35.9
	Total........	14,220	16,140	17,640	16,000	262.0	16,320	270.3

TABLE 5. — DRY MATTER AND NITROGEN TAKEN FROM NONLEGUME SUBPLOTS

POUNDS PER ACRE

		WITH FERTILIZER NITROGEN (Plots 5, 8, 10)					WITHOUT NITROGEN (Plots 6, 7, 9)	
Year	Crop	Dry Matter				Nitrogen Average	Dry Matter Average	Nitrogen Average
		Plot 5	Plot 8	Plot 10	Average			
1924	Grass............	4,280	4,260	3,040	3,860	27.4	1,360	10.9
1926	Japanese millet...	8,600	9,540	9,420	9,180	80.1	6,580	50.1
1928	Grass............	3,840	3,420	4,200	3,820	39.9	3,340	30.2
1930	Japanese millet...	7,500	7,040	6,560	7,040	79.8	6,820	69.3
1932	Hungarian millet..	5,680	4,900	5,580	5,380	52.3	3,480	28.1
1935	Oats.............	4,600	4,320	4,480	4,460	53.5	2,300	24.7
	Total........	34,500	33,480	33,280	33,740	333.0	23,880	213.3
	WITH RESIDUAL NITROGEN							
1925	Sweet corn.......	2,080	2,160	2,800	2,340	33.4	2,030	28.1
1927	Sweet corn.......	2,320	2,460	2,780	2,520	45.1	2,580	44.2
1929	Grass............	1,780	1,680	2,320	1,920	19.1	1,280	12.3
1931	Oats.............	1,680	2,000	2,500	2,060	26.5	2,040	26.3
1934	Hungarian millet..	3,540	4,040	4,620	4,060	36.5	3,780	32.7
	Total........	11,400	12,340	15,020	12,900	160.6	11,710	143.6

Plots 5, 6, and 8 had received sulfate of ammonia as the nitrogen fertilizer each year until the beginning of the present experiment. The results of this unequal liming were noticeable. The crops of corn in 1919 and of hay in 1920 and 1921 have been reported in Bulletin 290. Plot 8 was superior to the other two and Plot 6 inferior to the others. The corn crop of 1922, unreported until now, showed the west half of Plot 6 to be nearly barren, due to toxic compounds formed in the soil from the sulfate of ammonia in the absence of carbonate of lime. The reserve of lime on the east half maintained the yield at the level of Plot 8. The southwest quarter of Plot 5 was nearly as bad as the west half of Plot 6, and its northwest quarter was inferior to Plot 8. Table 7 shows the yields by quarter-plots.

PREPARATORY TREATMENT WITH LIME

In 1923 graduated amounts of ground limestone were applied to the plots in the spring before corn was planted. Plots 5, 9, and 10 received 1000 pounds per acre on the northeast quarter, 2000 pounds on the southeast and northwest quarters and 4000 pounds on the southwest quarter. Plot 7 received no limestone on its northeast quarter, 500 pounds per acre on the southeast and northwest quarters and 1000 pounds on its southwest quarter. Plot 6 was given 2000 pounds per acre on its east half and 4000 pounds on its west half. Plot 8 received one-half as much limestone as Plot 6. Table 6 gives the arrangement of the liming.

TABLE 6. — POUNDS PER ACRE OF LIMESTONE APPLIED IN 1923

Plot	Form of Nitrogen	Southwest	Northwest	Southeast	Northeast
5	Ammonia	4,000	2,000	2,000	1,000
6	Ammonia	4,000	4,000	2,000	2,000
7	None	1,000	500	500	None
8	Ammonia	2,000	2,000	1,000	1,000
9	None	4,000	2,000	2,000	1,000
10	Dry fish	4,000	2,000	2,000	1,000

The corn crop of 1923 was more nearly uniform throughout the plots than that of the year before. The yields were not as large, which is often observed when corn is planted for the second season after turning under sodland.

Table 7 shows the weights per quarter-plots in 1923. The southwest quarters of Plots 5 and 6 had regained much of their productive power.

The crop yields of 1924, 1925, and 1926 showed that Plots 5 and 6 had completely recovered from the toxic influence apparent in 1922.

TABLE 7. — YIELDS OF CORN IN 1922 AND 1923
POUNDS PER ACRE

Plot		Southwest		Northwest		Southeast		Northeast	
		Ears	Stover	Ears	Stover	Ears	Stover	Ears	Stover
	1922								
5	Ammonia	9	19	72	70	130	135	134	132
6	Ammonia	7	13	19	32	123	148	126	141
7	None	79	105	95	112	114	133	115	134
8	Ammonia	116	127	122	122	131	145	123	150
9	None	106	98	100	132	99	117	115	150
10	Dry fish	118	143	131	151	137	150	137	136
	1923								
5		66	61	82	77	120	85	119	98
6		62	70	73	72	119	94	116	93
7		73	84	81	87	101	90	106	108
8		102	94	105	96	117	100	115	105
9		69	83	83	89	98	83	98	89
10		115	94	111	88	128	99	135	116

PERIODICAL TREATMENT WITH LIME

The soil reaction of each subplot was measured periodically and application of limestone made in accordance with the results obtained. The values for pH on Plots 7, 9, and 10 fluctuated from 6 to 7, but most of the time at intermediate points between. Plot 8 with its sulfate of ammonia lost its reserve of carbonate of lime more quickly and Plots 5 and 6 formerly treated with the same fertilizer also showed similar exhaustion, manifested by the drop of pH values to 5.4 as the low point.

In 1927 the low pH values were found before corn was planted, and 1000 pounds per acre of ground limestone were applied to the west half of every plot. Again in October, 1930, the low pH of 5.5 was observed on the same three plots. The following spring, 1931, 2000 pounds per acre of ground limestone were applied over all plots. Because alfalfa was to be seeded in 1933, 2000 pounds of limestone per acre were again applied throughout all plots. In 1934, pH values ranged from 6.4 to 7.0 throughout the field. The west half of Plot 5 was at the lower limit and Plot 9 at the higher limit on all subplots. The nitrogen fertilizers applied in 1933 were calcium nitrate on Plot 5, leunaphos on Plot 8, and calurea on Plot 10, equivalent to 45 pounds of nitrogen per acre for each chemical. A like application was made in 1935.

NITROGEN AND ORGANIC MATTER IN SOIL AND SUBSOIL

To supplement the evidence obtained by analyzing the crops for nitrogen, the soil of every subplot was analyzed in 1924, 1927, 1931, and 1934. Each sample was taken from the center and four corners of the square rod at the center of the subplot. Conditions at these five points were considered to change similarly to the average changes on the whole subplot in the intervals between samples.

Early spring in 1924 was wetter than normal and the soil was too sticky to be sampled until June. Fertilizers had been applied before this date and the plots with nitrogen were superior in the growth of crops on them. Only the plots without nitrogen were sampled in June. The plots with nitrogen were left until November when the samples might represent more or less exhaustion of the fertilizer nitrogen.

The June samples were drawn from three depths, (a) surface to 8 inches; (b) 8 to 20 inches; (c) 20 to 32 inches. The last depth was difficult to secure with the soil auger because an irregular layer of pebbles interfered with its penetration. There was very little organic matter visible and this sample was omitted in all later work. Fragments of vegetable matter on the surface were avoided with the auger. Roots within the soil were included in the sample when it was prepared for analysis.

In 1927 the samples were collected in October after the crop of sweet corn had been harvested. The samples in 1931 were taken in August after the removal of the oats and peas. In 1934 the soil was too dry for sampling when the Hungarian millet was cut, and samples were taken the last of August, after showers had moistened the soil sufficiently to allow the use of the auger. Nitrogen had been withheld from Plots 5, 8, and 10 in each of these years, and the comparatively small effect of residual nitrogen on crops indicated that fertilizer nitrogen had been exhausted before the soils were sampled.

Each sample was dried in the air and then a subsample was separated by quartering. The subsample was dried in the oven and ground in an iron mortar until all of it passed through a half-millimeter sieve. This material was used for the determination of total nitrogen and organic matter. Total nitrogen was determined by the Kjeldahl-Gunning method modified for nitrates. The distillates from the subsoil samples were Nesslerized instead of titrated.

Analyses made at intervals of three and four years may be subjected to variations in reagents used at the different periods. To check this possible variation, several samples from 1924 and 1927 were analyzed simultaneously with the samples of 1931. Samples of 1924 were increased by the proportion of 100:110, but those of 1927 were unchanged. Samples from 1931 were repeated in 1934, with no appreciable change.

All the work of taking and preparing samples of the soils and of the chemical analyses were performed by the writer, which may have lessened the probable variations in manipulation from period to period.

Organic matter was determined in the samples of 1924, 1927, and 1931 by the method described in *Soil Science* by Schollenberger. An electric heater was substituted for a gas burner because it could be more easily regulated to a uniform heat.

Comparisons of the numerical data by plots and subplots and by years fail to bring out any positive accumulation of nitrogen in the soils of Plots 5, 8, and 10, which received nitrogen fertilizers, and do not show any loss of nitrogen from Plots 6, 7, and 9, which did not receive any nitrogen throughout the experiment.

Organic matter in soils may be expected to vary with the root systems of the crops grown upon them. The clovers and grasses of 1924 appear to have developed the highest percentages of organic matter by a small margin over the corn crop of 1927 and the oats and peas of 1931. The percentages in 1927 are the lowest.

Comparison of legume subplots with nonlegume subplots reveals a positive

TABLE 8. — PERCENTAGES OF NITROGEN AND ORGANIC MATTER SURFACE SOIL, DEPTH 8 INCHES

Plot	Supblot	Nitrogen				Organic Matter		
		1924	1927	1931	1934	1924	1927	1931
5	West Legume	.13	.15	.14	.14	3.20	3.12	3.07
	West Nonlegume	.14	.19	.17	.15	3.70	3.37	3.22
	East Legume	.13	.15	.15	.14	3.70	3.22	3.25
	East Nonlegume	.15	.21	.14	.18	3.95	3.92	3.92
6	West Legume	.15	.16	.15	.14	3.40	2.97	3.00
	West Nonlegume	.14	.17	.17	.15	3.40	3.20	3.15
	East Legume	.14	.17	.18	.15	3.50	3.15	3.30
	East Nonlegume	.14	.21	.18	.18	3.97	3.75	3.78
7	West Legume	.15	.17	.16	.14	3.00	2.82	3.25
	West Nonlegume	.12	.18	.16	.15	3.27	3.12	3.25
	East Legume	.13	.17	.17	.17	3.70	3.30	3.62
	East Nonlegume	.13	.21	.18	.17	4.07	4.22	4.12
8	West Legume	.12	.16	.15	.14	3.02	2.70	2.78
	West Nonlegume	.13	.16	.13	.14	3.25	3.30	3.05
	East Legume	.13	.16	.17	.16	3.27	3.10	3.27
	East Nonlegume	.16	.22	.18	.17	4.25	4.22	4.00
9	West Legume	.12	.14	.16	.13	2.97	2.37	3.25
	West Nonlegume	.13	.16	.14	.14	3.12	2.98	2.90
	East Legume	.14	.15	.18	.16	3.25	2.97	3.50
	East Nonlegume	.13	.20	.17	.17	4.17	4.15	4.10
10	West Legume	.13	.15	.17	.13	3.30	2.92	3.20
	West Nonlegume	.16	.19	.19	.16	3.55	3.45	3.32
	East Legume	.15	.25	.17	.16	3.62	3.45	3.50
	East Nonlegume	.18	.21	.17	.17	4.45	4.12	4.25

TABLE 9. — RATIOS OF NITROGEN TO ORGANIC MATTER SURFACE SOIL, DEPTH 8 INCHES

Plot	Subplot	1924	1927	1931
5	Legume	1:26.4	1:20.5	1:22.2
5	Nonlegume	1:26.4	1:17.7	1:23.4
6	Legume	1:23.3	1:18.4	1:19.5
6	Nonlegume	1:25.7	1:18.3	1:19.4
7	Legume	1:23.8	1:18.4	1:20.0
7	Nonlegume	1:29.5	1:18.3	1:21.2
8	Legume	1:25.3	1:17.5	1:18.5
8	Nonlegume	1:25.3	1:19.5	1:22.3
9	Legume	1:24.6	1:18.1	1:20.1
9	Nonlegume	1:27.2	1:20.0	1:22.5
10	Legume	1:25.0	1:19.3	1:19.3
10	Nonlegume	1:23.4	1:19.0	1:21.0

inferiority in both nitrogen and organic matter of the west legume subplots and equally definite superiority of the east nonlegume subplots, but the adjacent west nonlegume and east legume subplots run closely alike. Long-time observation of the field causes the belief that the differences between the two outer tiers of subplots are due to soil texture and moisture and not to crops or fertilizers. Like the nitrogen fertilizers, legumes and nonlegumes have left no permanent effects on these soils.

F. Loehnis in *Soil Science* has pointed out that the effects of legumes on succeeding crops soon pass off.

Ratios between nitrogen and organic matter were calculated and averaged for legume subplots and nonlegume subplots on each plot and are tabulated for each year. When nitrogen was added in 1924 to Plots 5, 8, and 10, the ratios of the two series of subplots were practically alike on these plots. For Plots 6, 7, and 9 which were without nitrogen, the ratios were narrower on the legume subplots. In 1931, when nitrogen was withheld from all plots, the legume subplots with oats and peas showed slightly narrower ratios on all plots than the nonlegume subplots with oats. Corn on all plots in 1927, with no nitrogen on all plots, appeared to give a fairly uniform lot of ratios.

The nitrogen in the subsoils varied within such narrow limits around .05 percent that results were averaged by plots and tabulated. In 1924, the plots which had received nitrogen were definitely higher in subsoil nitrogen than the plots which had been without nitrogen. In 1927, the variations were not important. Organic matter in the subsoil ranged from 1.16 to 1.61 with no positive trend.

The subsoil 20 to 32 inches depth did not exceed .027 nitrogen and averaged .012 on Plot 6, .015 on Plot 7, and .018 on Plot 9. Organic matter in Plot 7 was .63 percent and .69 percent in Plot 9. Such small proportions of organic matter and nitrogen at this depth bear out Latimer's statement that Massachusetts soils are seldom weathered beyond 30 to 36 inches in depth, as shown in the Soil Surveys.

TABLE 10. — PERCENTAGES OF NITROGEN AND ORGANIC MATTER IN SUBSOIL

Plot	Nitrogen		Organic Matter	
	1924	1927	1924	1927
Subsoil, depth 8 to 20 inches				
5	.05	.05	....	....
6	.03	.055	....	....
7	.02	.06	1.51	1.54
8	.05	.055	1.31	1.43
9	.035	.06	1.46	1.16
10	.06	.07	1.61	1.32
Subsoil, depth 20 to 32 inches				
6	.012		......	
7	.015		.63	
9	.018		.69	

NONLEGUME CROPS CONTINUOUSLY

A prime objective of this investigation was the effect on crops and on soils of the continued production of nonlegume crops without nitrogen fertilizers. Plots 7 and 9 have not had nitrogen fertilizers since 1882, a period of 53 years. During the first 9 years, nonlegume crops were grown continuously. After 1891, legume crops were frequently used until 1921, when a crop of mixed clover and grass was the last to occupy the entire plots.

The early series of nonlegume crops are tabulated for comparison with the series just completed. Weights of the early crops have been taken from Bulletin 290 and were made on field-dry material. Weights of nitrogen have been calculated by using analytical data obtained from these crops and similar ones in the experiment station laboratory. The late series in the table includes the data from the nonlegume subplots of Plots 7 and 9. Dry matter and total nitrogen were determined for each subplot. The first crop of corn in the early series had been grown on a "run-out" grass sod that probably bore little if any clover. The late series was preceded by two crops of corn that must have removed all effects of the last crop of mixed grass and clover.

The amounts of nitrogen contained in stubble and roots of crops, which may be used by succeeding crops, are difficult to measure and few have attempted to do so. Woods is reported in the Connecticut (Storrs) Experiment Station Report for 1889 to have found 90 pounds per acre of nitrogen in the roots and sod of timothy and 60 pounds per acre in roots and stubble of clover. The two corn crops of 1922 and 1923 were calculated to have contained 87 pounds of nitrogen in 1922 and 71 pounds in 1923, which should have taken up the residual nitrogen of the preceding crops.

TABLE 11. — NONLEGUMINOUS CROPS. POUNDS PER ACRE OF CROP AND NITROGEN, 1883 – 1891

Year	Crop	Yield — Pounds			Nitrogen Pounds per Acre	
		Plot 7	Plot 9	Average per Acre		
1883	Corn, ears	197	191	1,940	25.2	
	stover	356	355	3,555	24.9	50.1
1884	Corn fodder	458	458	4,580		31.0
1885	Corn fodder	P 280	K 948	6,125		42.8
1886	Corn fodder	P 255	K 840	5,475		38.3
1887	Corn fodder	PK 730	K 655	6,925		48.4
1888	Corn fodder	K 676	K 553	6,145		43.0
1889	Corn, ears	PK 41	PK 58	495	6.4	
	stover	484	417	4,505	31.5	37.9
1890	Oats, grain	PK 110	PK 101	1,055	19.0	
	straw	210	189	1,995	11.9	30.9
1891	Rye, grain	PK 109	PK 109	1,090	17.4	
	straw	341	316	3,285	16.4	33.8
	Total			47,170		356.2

P — Phosphoric acid K — Potash

TABLE 12. — NONLEGUMINOUS CROPS. POUNDS PER ACRE OF DRY MATTER AND NITROGEN, 1924–1935. PLOTS 7 AND 9, WITHOUT NITROGEN FERTILIZER SINCE 1882

Year	Crop	Dry Matter	Nitrogen
1924	Grass	990	8.7
1925	Sweet corn	2,120	28.5
1926	Japanese millet	4,760	33.4
1927	Sweet corn	2,630	44.4
1928	Grass	3,370	30.0
1929	Grass	1,230	12.0
1930	Japanese millet	6,800	70.9
1931	Oats	2,110	27.0
1932	Hungarian millet	3,580	29.2
1933	Barley	Plowed under	
1934	Hungarian millet	3,900	32.9
1935	Oats	2,290	25.6
Total		33,780	342.6

The two series of nonlegume crops differ in the crops grown and their succession. The early series is estimated to have removed in its 9 crops, 39.5 pounds per acre of nitrogen per year. The 11 crops in the late series are calculated to have removed 31.1 pounds per acre yearly, but with wide variations from the average. Grasses cut once in a season remove much less nitrogen than is contained in the turf and roots. Corn leaves only a small part of its nitrogen in its stubble and roots. Spring crops are less benefited by soil organisms than summer crops, which have a warmer soil at their time of growth.

Omitting the first crop of corn in the early series because it had the benefit of the grass sod, the other six corn crops averaged 40.2 pounds per acre of nitrogen per year. The late series, including the six summer crops of sweet corn, Japanese and Hungarian millets, had a yearly average of 39.9 pounds of nitrogen. The soil of these two plots again supplied nitrogen to crops under summer conditions at the rate of 40 pounds per acre, without measurable deterioration, although 40 years had elapsed during which any additions of nitrogen must have been through soil microorganisms.

This experiment is not absolute proof of the fixation of nitrogen by soil organisms in the absence of legumes. Circumstantial evidence, however, favors such fixation.

Of the five crops grown on the nonlegume subplots with residual nitrogen, grasses alone showed striking response to the fertilizer residue when compared with the subplots without nitrogen fertilizer. Six crops on the same subplots with nitrogen fertilizer exceeded those on the subplots without it, yet they had recovered less than half of the added nitrogen in comparison with that taken wholly from the soil of the other plots. One-half the applied nitrogen seems unnecessary because some soil agent appears capable of keeping up a moderate supply, year after year.

Bradley and Fuller have studied the nitrogen-fixing powers of soils taken from these different subplots and of bacteria isolated from the soils, results of which they have reported in *Soil Science*. Both soil and soil bacteria showed active fixation of nitrogen from the air under laboratory conditions.

Legume bacteria, the ability of which to fix nitrogen from the air has been accepted for years, have been shown by Allison in the *Journal of Agricultural Research*, and by Hopkins and by M. Loehnis in *Soil Science*, to be unable to do so when the roots of legumes are not present in the soil. Legume influence in the nonlegume subplots must have been reduced to the minimum, if not wholly eradicated.

Discussing in *Soil Science* the work of the First International Congress of Soil Science, Waksman asserted that the literature about Azotobacter presented no valid proof that such bacteria were of any use in the soil under field conditions. Winogradsky, in the Congress, pointed out that organic matter and temperatures used in laboratory studies were wholly unlike known conditions in the field. Nevertheless, the studies by Bradley and Fuller showed that there were possibilities of fixation of nitrogen in these plots from the air about them, though their laboratory temperature was 82° F., which is possibly never reached in our soils, although even higher temperatures are found in soils of some sections of our country. Vandercaveye and Villanueva of the Washington Agricultural Experiment Station have recently reported laboratory experiments with virgin soil, which showed in 80 days, at temperatures between 69° and 76° F., fixation of nitrogen from the air, equivalent to 216 pounds per acre in the field, with only the soil organic matter. When filter paper was supplied together with lime, the amount of fixed nitrogen was more than doubled. These observations of Bradley and Fuller and of Vandercaveye and Villanueva aid in explaining the greater content of nitrogen in the summer crops like corn and the millets, which are growing during the season of highest temperatures.

Waksman, describing the decomposition of organic matter in the soil, states that it finally becomes humus and most of the soil nitrogen is contained in soil humus. This material is often so stable that its nitrogen cannot be used by plants, and plants will not thrive without added nitrogen in available forms. Our repeated analyses of these soils indicate a somewhat stabilized percentage of nitrogen, equivalent to approximately 3000 pounds per acre in the depth of soil sampled. It has been already noted that legume fixation has not apparently caused accumulation of nitrogen beyond the capacity of the growing crops to use it. It is equally apparent that nonlegume crops have not lessened the nitrogen in the soil as analyzed. It appears reasonable that continued growth of nonlegumes on a soil wtihout nitrogen fertilizers maintains the soil nitrogen, but limits crop production to a lower level than is possible when legume crops are alternated with nonlegumes.

USE OF NITROGEN FROM THE AIR

The classic experiment of Lawes and Gilbert in 1858 proved that plants could not use nitrogen from the air through their leaves as they were known to use carbon dioxide, and their use of air nitrogen was doubted in 1883, when Field A was laid out. By 1889, when the plots were devoted to a comparison of nitrogen fertilizers, it had just been shown by Wilfarth and Hellriegel that nodules on the roots of clovers, peas, and similar plants contained bacteria that supplied the plants with nitrogen which came from the air and not from the soil. Soybeans and clovers were introduced into rotations from time to time. The importance of such crops in agricultural practice had long been known. The scientific explanation of their value has now become common knowledge.

Winogradsky in 1895 reported his discovery of a microorganism in the soil which could use air nitrogen without the roots of clovers for living quarters. Beijerinck in 1902 described another kind of bacteria yet more capable of combining air nitrogen into nitrogen compounds of use to plants. Winogradsky, in *Soil Science* for July 1935, offers a method for their study which can be related to natural soil conditions.

Nitrogen fertilizers in 1889 were the natural deposit of nitrate of soda and by-products like ammonium sulfate from gas works and animal refuse from abattoirs. Chemical synthesis of nitrogen from the air with oxygen also from the air had long been possible in the laboratory but was impracticable on a commercial scale. Development of water power and electrical energy in Norway enabled Dr. Eyde to report the successful commercial development of synthetic nitric acid and nitrate of lime at the International Congress of Applied Chemistry in New York in 1912. At the same meeting, Dr. Haber demonstrated his synthesis of ammonia from air nitrogen and hydrogen. Several years earlier, Ostwald had developed the catalytic oxidation of ammonia to nitric acid. From 1914 to 1918, these two inventions of Haber and Ostwald enabled Germany to make ammunition from an inexhaustible source of raw materials.

Since the World War, every nation seeks to provide itself with means to synthesize nitrogen, hydrogen, and oxygen into ammonia and nitrates. A wholly new set of conditions, both scientific and economic, now surrounds the use of fertilizers. Fertilizer experiments must be rearranged to meet new problems.

SUMMARY

For 12 years, continuous production of nonlegume crops has been compared with the alternation of a legume with a nonlegume crop.

Continuous absence of nitrogen fertilizers has been compared with the alternation of applied nitrogen with residual nitrogen.

Nitrogen applied to legume crops produced no practical gain with clovers, about 7 percent increase with soybeans, and between 8 and 9 percent increase with mixed oats and peas. Nitrogen applied to six nonlegume crops increased their total product 41 percent.

Residual nitrogen and absence of nitrogen produced virtually equal yields on the legume subplots. Residual nitrogen produced 10 percent more dry matter on the nonlegume subplots.

On plots which received nitrogen it was applied in 7 years out of 12, to the total amount of 315 pounds per acre. On these plots, alternation of legume crops with nonlegume crops produced in 11 harvests a total of 41,580 pounds per acre of dry matter containing 750.1 pounds of nitrogen; continuous nonlegume crops produced 46,640 pounds of dry matter and 493.6 pounds of nitrogen. The nonlegume subplots produced 12 percent more dry matter, but 34 percent less nitrogen than was produced by the legume subplots.

On the plots which did not receive nitrogen fertilizers, alternation of legume crops with nonlegume crops produced 40,120 pounds per acre of dry matter containing 741.7 pounds of nitrogen; continuous nonlegume crops produced 35,590 pounds of dry matter and 356.9 pounds of nitrogen. The nonlegume subplots produced 11 percent less dry matter which contained 52 percent less nitrogen than was produced by the legume subplots.

Application of nitrogen to the legume crops appeared to be practically needless. The nonlegume crops recovered only 43.3 percent of the nitrogen supplied to them.

Of the plots continuously without nitrogen, clover sod produced larger yields of succeeding crops than did grass sod. Soybean stubble was less effective than Japanese millet stubble. Hungarian millet was slightly better following alfalfa plowed under than following barley plowed under.

Analyses of the soils showed no evidence of accumulation of nitrogen by the application of nitrogen fertilizers or by the growth of legume crops. Continuous production of nonlegume crops did not measurably deplete the soil nitrogen. Ratios of nitrogen to organic matter were slightly narrower when legume crops occupied the plots without nitrogen fertilizers. From past records of Field A and analytical data reported by the Experiment Station, it is estimated that Plots 7 and 9 had produced from 1884 to 1889 six crops of corn without nitrogen fertilizer which had contained a total of 20,520 pounds per acre of dry matter and 241.4 pounds per acre of nitrogen. From the nonlegume subplots of these same plots, between 1925 and 1934 inclusive, six crops of summer nonlegumes were produced, including two crops of sweet corn, two crops of Japanese millet, and two crops of Hungarian millet. Weighed, sampled, and analyzed, these crops contained 23,790 pounds per acre of dry matter and 239.3 pounds of nitrogen. During the 40 intervening years the plots had not received nitrogen fertilizers, and legumes had been eliminated from the nonlegume subplots. The soil appeared capable of supplying to nonlegume crops growing during the summer months an average of 40 pounds per acre of nitrogen, with no measurable depletion.

Grasses and spring grains appeared to be unable to secure as large an amount of nitrogen from the soil without nitrogen fertilizers. Microorganisms are less active in the soil at springtime temperatures.

Results obtained with the legume crops are in accord with the accepted facts about the synthesis of nitrogen from the air by symbiotic bacteria in the soil. Results with the nonlegume crops are strongly indicative of the presence in the soil of nonsymbiotic microorganisms which are adding to the supply of nitrogen that is available for such crops.

Publication of this Document Approved by Commission on Administration and Finance
3m — 8-'36. No. 8410.

l l 4 b
3
334

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 334 October, 1936

Dried Blood as a Source of Protein For Dairy Cows

By J. G. Archibald

The successful use of high-grade tankage as a feed for dairy cows has raised the question whether other by-products of the meat packing industry may be so utilized. Dried blood was considered deserving of study in this connection.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

DRIED BLOOD AS A SOURCE OF PROTEIN FOR DAIRY COWS

J. G. Archibald
Assistant Research Professor of Animal Husbandry[1]

INTRODUCTION

A year ago Bulletin No. 321 of this station was published setting forth the results of feeding high grade tankage to milking cows. Since the results were entirely favorable the question arose as to whether other by-products of the meat packing industry might also be utilized to advantage for this purpose. Dried blood was chosen for a trial since it is the only other abattoir by-product of considerable volume, which is low enough in price to compete as a possible source of protein with the commonly used protein concentrates.

Dried blood is just what the name indicates. According to Morrison[2], "the blood is collected . . . and heated in large vats until it is thoroughly coagulated. The excess water is drained off and more moisture is removed in a hydraulic press. The solid residue is then dried and ground to form blood meal or dried blood." The protein content is very high, usually between 80 and 85 percent. Dried blood should not be confused with "soluble blood flour," a specially prepared article which has been used considerably as an ingredient of calf meals, and which commands a somewhat higher price.

METHOD OF CONDUCTING THE INVESTIGATION

A feeding trial of dried blood similar to that conducted for tankage in 1934–35 was carried on during the winter of 1935–36, lasting from November 18 to April 25. Twenty-two cows in the State College herd were available for the experiment. These were divided into two groups of eleven each, as nearly alike as possible with respect to breed, age, live weight, stage of lactation, amount of milk being produced, and fat test of the milk. Table 1 shows the similarity in these respects.

The dried blood used in the experiment was the usual commercial article. It was compared with a mixture of equal parts of soybean meal and cottonseed meal, 10 percent of it being included in the experimental grain mixture. The groups of cows were fed by the double reversal method, one group receiving the dried blood for forty days while the other received the soybean–cottonseed ration. At the end of that time the rations were reversed and the reversal was repeated three times throughout the season, so that each group received each ration for two different periods of forty days each. As is customary, results have been reckoned from the last thirty days of each period, the first ten days being considered preliminary, to allow the cows to become accustomed to the change in feed and to take care of any lag in the effect of the previous ration

---

[1] The author desires to make the following acknowledgments: To Wilson & Co., Chicago, who supplied the dried blood used in the experiment; to C. H. Parsons, farm superintendent for his cooperation in the conduct of the work; and to Thomas Muir, herdsman, who had immediate charge of the animals and the details of feeding.

[2] Morrison, F. B. Feeds and Feeding. 20th Edition. 1936.

on milk production. Table 2 shows the schedule of the experiment. The composition of the grain mixtures is given in Table 3.

TABLE 1. — STATUS OF THE TWO GROUPS AT THE BEGINNING OF THE EXPERIMENT

	Group A	Group B
Breed:		
Shorthorns	2	2
Ayrshires	2	1
Holsteins	4	5
Guernseys	2	1
Jerseys	1	2
Average age	6 years, 6 months	5 years 9 months
Average weight	1211 pounds	1202 pounds
Average stage in lactation	77 days	82 days
Average daily milk yield	36.9 pounds	36.9 pounds
Average butter fat	4.13 percent	4.07 percent

TABLE 2. — SCHEDULE OF FEEDING PERIODS

Period	Ration fed to Group A	Ration fed to Group B
Nov. 18 — Dec. 27, inclusive	Soybean–cottonseed	Dried blood
Dec. 28 — Feb. 5, inclusive	Dried blood	Soybean–cottonseed
Feb. 6 — Mar. 16, inclusive	Soybean–cottonseed	Dried blood
Mar. 17 — Apr. 25, inclusive	Dried blood	Soybean–cottonseed

TABLE 3. — FORMULAS OF GRAIN MIXTURES

Ingredients	Soybean–cottonseed Meal mixture (pounds)	Dried blood mixture (pounds)
Wheat bran	400	400
Ground oats	500	500
Hominy feed	640	640
Soybean meal (41% protein)	200	...
Cottonseed meal (41% protein)	200	...
Corn starch	...	200
Dried blood	...	200
Steamed bone meal	40	40
Salt	20	20
TOTAL	2000	2000

The amounts of soybean meal and cottonseed meal in the standard grain mixture were chosen as typical of the percentages of these ingredients occurring in commercial dairy rations. With two exceptions the mixtures were similar. Due to its much higher content of protein, 200 pounds of dried blood furnished an amount of protein equivalent to that contained in 200 pounds each of the two oil meals. The other 200 pounds necessary to make a ton of the mixture was made up by adding that amount of corn starch, a material which contains no protein.

Except for the variation in the grain mixtures the rations were kept as nearly identical as possible. Table 4 shows that the average daily intake of feed by the two groups was practically identical. The only feed wasted was a small amount of hay which has been deducted from the total in Table 4, and which was practically the same for both groups.

The composition of the feeds as set forth in Table 5 has been used together with average digestion coefficients and the values in Table 4 to obtain the intake of nutrients as recorded in Table 6. It will be noted that the figures for both rations are substantially the same.

TABLE 4. — AMOUNTS OF FEED EATEN

Feed	Soybean–Cottonseed Ration		Dried Blood Ration	
	Total for the Group (Pounds)	Daily Average per Cow (Pounds)	Total for the Group (Pounds)	Daily Average per Cow (Pounds)
Hay and rowen	14,625	11.08	14,625	11.08
Corn silage	51,795	39.24	51,795	39.24
Roots[1]	15,024	11.38	15,024	11.38
Dried beet pulp[2]	1,650	1.25	1,650	1.25
Grain	13,685	10.37	13,553	10.27

[1] Fed from the beginning in November through February 5; a mixture of white turnips and mangels.

[2] Fed from February 6 to the end of the trial. Moistened with an approximately equal amount of water before feeding.

TABLE 5. — COMPOSITION OF THE FEEDS[1]

Material	Water	Ash	Crude protein	Crude fiber	Nitrogen-free extract	Crude fat
Hay	11.97	6.54	8.78	29.94	41.24	1.52
Rowen	12.57	7.37	12.10	25.14	40.79	2.01
Corn silage	75.70	1.28	2.05	6.60	13.79	.58
Mangels	92.58	1.15	.93	.63	4.67	.04
Turnips	93.89	.61	.65	.62	4.19	.05
Dried beet pulp	14.00	3.65	9.37	18.54	54.17	.28
Soybean–cottonseed mixture	12.45	6.39	18.10	6.55	51.65	4.87
Dried blood mixture	12.81	5.49	17.85	4.91	55.22	3.72
Dried blood	14.15	3.13	81.11	none	1.21	.39

[1] Expressed on the basis of percentages in the materials as fed, except dried beet pulp to which water was added before feeding.

TABLE 6. — AVERAGE DAILY INTAKE OF NUTRIENTS PER COW[1]

	Soybean–cottonseed Ration	Dried Blood Ration
Total dry matter	30.22 pounds	30.09 pounds
Total ash	2.08 pounds	1.98 pounds
Digestible protein	2.78 pounds	2.76 pounds
Total digestible nutrients	21.74 pounds	21.82 pounds
Net energy	20.43 therms	20.63 therms
Nutritive ratio	1:6.8	1:6.9

[1]This includes all material fed, not merely the grain mixtures.

RESULTS OF THE FEEDING TRIAL

Palatability of the Dried Blood

No difficulty was experienced in getting the cows to eat the grain mixture which contained the dried blood. It was not relished as keenly as was the standard mixture, but was not refused at any time.

Changes in Live Weight

The cows were weighed when the trial was started and thereafter at the end of each forty-day feeding period, just previous to the change of rations. Weighings were made on two consecutive days in all cases, and the average of the two weights was taken. Table 7 shows that the cows made average individual gains of 24 pounds more on the standard ration in 160 days than they did on the ration containing dried blood. Calculation of the probable error shows this difference in favor of the standard ration to be slightly significant.

TABLE 7. — SUMMARY OF AVERAGE GAINS IN LIVE WEIGHT

	On Soybean–cottonseed Ration (Pounds)	On Dried Blood Ration (Pounds)
First 40-day feeding period	24	21
Second 40-day feeding period	34	26
Third 40-day feeding period	23	11
Fourth 40-day feeding period	38	37
Total	119[1]	95[1]

[1]These values represent average gains by individual cows.

General Appearance of the Cows

There was no difference apparent to the eye in the condition of the animals on the two rations.

TABLE 8. — MILK PRODUCTION (CORRECTED TO 4 PERCENT FAT)

	On Soybean–Cottonseed Ration (Pounds)	On Dried Blood Ration (Pounds)
First 30-day period	10,914.8	10,682.8
Second 30-day period	10,118.3	9,887.6
Third 30-day period	9,208.0	8,526.1
Fourth 30-day period	7,839.4	7,868.5
Total production	38,080.5	36,965.0
Average daily production per cow[1]	28.9	28.0

[1] Obtained by dividing the total by 1320, the number of cow days on each ration.

Milk Production

This is summarized in Table 8. The figures given have been corrected to a uniform fat basis of 4 percent by the usual formula (.4M + 15F) in which M equals actual milk production and F equals calculated fat production based on the fat test of the milk and the actual milk production. Due to the fact that the average fat test of both groups was quite close to 4 percent, the corrected values do not differ greatly from the actual milk production.

The results show an apparent moderate difference in milk production in favor of the standard ration, but calculation of the probable error of this difference shows that it is not significant. The fact that the cows did not decline significantly in milk production when approximately half of the protein in their grain came from the dried blood is a fair indication that this material may be substituted for a similar amount of protein from ordinary protein concentrates with good results insofar as milk production is concerned.

Composition of the Milk

Composite milk samples were taken from each group of cows about midway of each feeding period. The sampling period was three days in length and samples from individual cows in a group were pooled to make a group sample. Table 9 shows that there was no significant difference between the rations in this respect.

TABLE 9. — COMPOSITION OF THE MILK (PERCENTAGES)

	On Soybean–cottonseed Ration	On Dried Blood Ration
Total solids	12.48	12.40
Fat	3.83	3.79
Ash	.721	.723

Flavor of the Milk[1]

The composite samples taken for analysis were also scored for flavor, preservative having been purposely omitted with this in mind. The samples were kept in a cool milk room and scored on the same day on which the final aliquots were taken.

Insofar as the rations were concerned there was no difference in flavor of the milk. The product from one group of cows without exception scored slightly higher than that from the other group, but it was always the same group irrespective of which ration they were receiving.

Curd Tension of the Milk

This factor was determined on two occasions on the samples used for analysis and flavor. No difference could be detected between the samples in this respect.

SUMMARY AND CONCLUSIONS

Dried blood has been compared as regards its suitability for dairy cows with a mixture of soybean meal and cottonseed meal. The comparison has been made by means of the double reversal method using twenty-two cows in the State College herd, divided into two groups of eleven each. The feeding period extended over 160 days, each group of cows being on each ration at two different times for periods of 40 days in length. Dried blood made up 10 percent of the experimental grain ration, and supplied digestible protein equal in amount to that in the 10 percent each of soybean meal and cottonseed meal which the control ration contained.

No difficulty was experienced in getting the cows to eat the grain mixture which contained the dried blood.

There was a slightly significant difference in gains in weight in favor of the control ration, but there were no significant differences between the two rations in any of the following respects: general appearance of the cows, milk production, composition, flavor, and curd tension of the milk.

Insofar as these results are concerned, it seems evident from the standpoint of palatability and the absence of any unfavorable effects on the animals that dried blood can be safely used as a component of grain mixtures fed to dairy cows to the extent of at least 10 percent of the mixture.

Also, in view of our general knowledge of the subject of the protein requirements of milking cows and the fact that there was not a significant difference in milk production on the two rations, it seems a reasonable conclusion that the blood was a satisfactory source of protein as a substitute for a mixture of soybean meal and cottonseed meal.

---

[1] Acknowledgment is made to M. J. Mack and H. G. Lindquist of the Department of Dairy Industry of Massachusetts State College who made the tests for milk flavor; and to W. S. Mueller of the same department, who determined the curd tension of the samples.

PUBLICATION OF THIS DOCUMENT APPROVED BY THE COMMISSION ON ADMINISTRATION AND FINANCE
4M,10-'36. No. 9010.

IA POLYTECHNIC I
RICULTURAL BRANCH LIBRAR
BLACKSBURG, VIRGINIA

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Bulletin No. 335 November, 1936

Some Factors Affecting the Properties of Whipping Cream and the Quality of the Finished Product

By W. S. Mueller, M. J. Mack, and H. G. Lindquist

This bulletin is intended to supply the dairyman with the information necessary to prepare whipping cream which will give a finished product of uniformly high quality.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

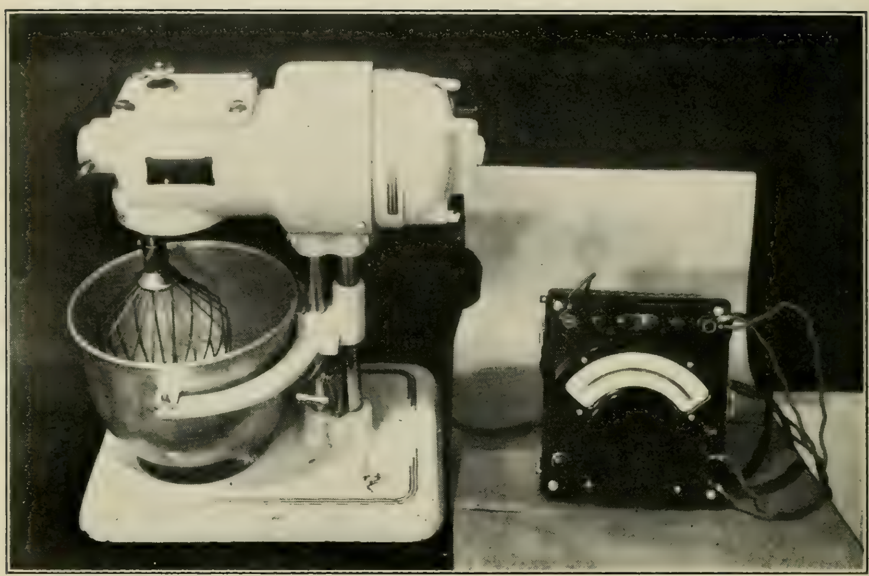


Figure 1. Mechanical Cream Whipper and Wattmeter.
(Gem kitchen mechanic whipper manufactured by Gem Appliances, Inc., 280 Madison Ave., N. Y., and a Westinghouse type PY5 portable single phase wattmeter.

With this apparatus it is possible to obtain a record of the stiffness of the cream throughout the whipping process by recording the input of the motor in watts at intervals of ten seconds, or less if desired. The smallest scale division on the wattmeter is 5 watts, but 2.5 watts can be readily estimated. The whipper-motor, of which the input is charted, is a split-phase motor rated 1/8 h.p. and 1725 r.p.m. This motor produces in the whipper proper two distinct kinds of rotation. First it spins the whipper on its vertical axis counter clockwise at a speed of 570 r.p.m. Second, it moves the spinning whipper (and its axis) clockwise about the inner periphery of the bowl so that the whipper completes 78 circuits about the bowl each minute. This motion prevents the whipped cream from clinging to the sides of the bowl and leaving the whipper relatively free.

SOME FACTORS AFFECTING THE PROPERTIES OF WHIPPING CREAM AND THE QUALITY OF THE FINISHED PRODUCT

By W. S. Mueller, Assistant Research Professor, M. J. Mack, Assistant Professor, and H. G. Lindquist, Assistant Professor, of Dairy Industry

INTRODUCTION

One of the problems of considerable importance to the dairyman is that of the whipping properties of cream. The housewife is prone to judge the products of a dairy by the whipping ability of cream obtained from that dairy. Whipping cream is a unique dairy product in that it is sold as a partly finished product; and inasmuch as some customers do not know how to whip cream properly, it thereby becomes a special problem to the dairyman.

Many milk dealers have tried to educate the consumer to the proper care of cream which is to be whipped. Other agencies have also helped by publishing circulars and leaflets on the subject of whipping cream. An example of this type of publication is circular No. 115 of the New York State Agricultural Experiment Station entitled, "How to Whip Cream."

Inability to whip cream satisfactorily may be the fault of the housewife. First of all, cream must be cold. From 40 to 45° F. is ideal, although cream can be whipped at temperatures between 45 and 55° F. All utensils must be cold so as not to warm the cream during the whipping process. A turbine type of whipper is satisfactory. The bowl should not be over-full. A cream testing between 30 and 35 percent fat, which has been held for at least four hours at the whipping temperature, should be used. If these requirements are met by the housewife, the cream should whip satisfactorily. If it does not, then there is reason to suspect the milk dealer who sold the cream.

The references in the literature pertaining to the question of whipping cream are too numerous to review thoroughly in this publication. The major factors affecting the whipping properties of cream have been studied frequently and, as a result, the majority of milk dealers are familiar with the principal factors involved. They know in general the effect of temperature changes, composition, and age, and how each step in the processing of cream affects whipping ability. However, some recent recommendations for increasing cream viscosity (1) may have an effect on the whipping properties of the cream so treated. The whipping ability of cream which had been cooled slowly so as to increase the viscosity was studied in this experiment.

Although a considerable amount of research has been published on cream whipping, virtually all the work is open to the criticism that hand-operated whippers were used. With a manually operated whipper a constant speed cannot be maintained from one trial to another; it is also impossible to stop all trials when the whipped creams are of the desired stiffness. Since both the percentage of overrun and the amount of serum drainage from whipped cream are affected somewhat by the stiffness of the whip, one can readily see that accurate comparisons cannot be made with manually operated whippers. The authors are aware of only the investigations of Templeton and Sommer (2) and Mueller (3) in which whippers of constant speed were employed.

Templeton and Sommer measured the consistency of the whipped cream by observing the torque (load) on the drive shaft of the turbine whipper. Mueller determined the consistency of whipped cream during the whipping process by observing the input in watts of the motor running the mechanical whipper. This latter method was used in this experiment.

Another purpose of this study was to check accurately with a mechanical whipper some of the previous research done with manually operated whippers. The bulk of the previous research covered a study of the more obvious factors affecting the whipping of cream. A reasonable assumption is that the conclusions reached in the majority of these studies are accurate. However, when less obvious factors having a slight effect are studied with manually operated whippers, the differences may not be noticed. It is true that some of the factors studied in this and other researches, in themselves are relatively unimportant under commercial conditions. It is likewise true that the effects are cumulative; hence, a number of minor factors may exist simultaneously and cause trouble.

The question is repeatedly asked, "Can some suitable substance be added to cream to improve the whipping ability of the cream?" The regulations in a number of states make such a practice illegal. However, the addition of milk solids, edible casein, or stabilizer is permissible in some states and cities and is practiced in others. In this investigation, tests were made of a number of substances, such as skim milk powder, condensed skim milk, gelatin, dehydrated egg yolk, dehydrated egg albumin, dehydrated sodium caseinate, "Dariloid" (sodium alginate), "Kraftogen", and "Vegetable Gelatin." The effects of these additions on the stiffness of whipped cream, the rate of whipping, the percentage of overrun, and the amount of serum drainage are discussed later in the publication.

EXPERIMENTAL PROCEDURE

In general the following experimental procedure was used throughout this study. Any variations from this procedure will be given with the presentation of the data. The cream was from mixed herd milk separated at the college creamery. As the richness of the cream at the separator varied from time to time, the cream was standardized immediately after separation with skim milk obtained from the same separation. For the first few experiments the cream was standardized to 36 percent fat, then to 30 percent for the later experiments. The cream was pasteurized (145° F. for 30 min.) in one-gallon ice cream cans set in hot water or in a small water-jacketed pasteurizer. After pasteurization the cream was cooled to 40° F. or lower by placing the cans in cold brine or pouring the cream over a small surface cooler. The cream was held for 24 hours at approximately 38° F. before being whipped.

The value of any cream-whipping study depends largely on the whipping method used. The whipper should have a constant speed, should be so constructed that the cream is in contact with the whipper throughout the whipping process, and should provide some means for measuring the stiffness of the cream while being whipped. The following simple method for measuring the stiffness of the cream during the whipping process was used in this experiment. The apparatus consists of the mechanical whipper (restaurant size) and sensitive wattmeter, shown in figure 1. The speed of the whipper was checked under all loads which are normally encountered when whipping cream up to 40 percent butterfat, and was found to be practically constant. Although the whipping bowl has a 5-quart capacity (liquid measure), only one quart of cream was usually placed in the bowl for whipping. The bowl was submerged in ice water thus keeping the temperature of the cream at approximately 40° F. during whipping, without the inconvenience of working in a cold room.

Since a good whipped cream should have a high degree of stiffness, all samples in this study were whipped to their maximum stiffness. This could readily be done with the type of whipper used without churning the cream.

The time necessary to whip the cream to its maximum stiffness was measured with a stop watch. The wattmeter reading was recorded at regular intervals. The increase in stiffness during whipping is shown graphically by plotting the motor input in watts against the time. The average watt increase per second is given in the tables. The whipping curve is not a straight line, yet the average increase in watts per second is in most instances sufficiently accurate for comparison of whipping ability. As the initial stiffness of the cream varied with the viscosity, the total increase in stiffness during whipping is reported rather than the maximum stiffness.

The overrun, or volume of air incorporated, was determined by weighing a definite volume of cream and an equal volume of whipped cream. The weighing was done on a Torsion balance (sensitivity 13 mg.), using a Torsion ice cream overrun cup (65 c.c. capacity).

Data on serum drainage were secured by filling a pint carton (having both ends removed) with whipped cream and placing it on 12-mesh wire screening over the mouth of a funnel. The drainage was collected in a graduated glass cylinder. After 24 hours in the cold room (approximately 38° F.) the volume of drainage was read and its fat content determined by the Minnesota Test.

The viscosity of the cream was generally determined with the pipette form of viscosimeter at a temperature of 68° F. In the first experiment the MacMichael viscosimeter was used. Samples were tempered to 68° F. in a constant temperature water bath, without agitation, and were poured through a 16-mesh wire screen before making the viscosity determination.

EXPERIMENTAL RESULTS

Whipping, Separation, and Pasteurization Temperatures

Since the whipping ability of cream may be affected by the type of whipper employed, it seemed desirable to study some factors which have already been studied by other investigators. The effect of temperature on cream whipping is generally known. However, this experiment was made because the type of whipper may affect the maximum temperature which can be used without reducing the quality of the whip. A 36 percent cream was whipped at varying temperatures and the results are given in Table 1 and Figure 2. It is obvious from this table and figure that the quality of the whip decreased as the temperature was raised above 40° F. With each increment of temperature increase above 40° F., the percentage of overrun and the maximum stiffness of the whipped cream decreased and serum drainage increased. At 65° F. the cream failed to whip. None of the samples churned during whipping, but they were progressively nearer churning as the temperature was raised. The results of this experiment fixed the desirable whipping temperature at approximately 40° F. for further studies.

TABLE 1. — EFFECT OF WHIPPING TEMPERATURE ON THE QUALITY OF WHIPPED CREAM

(Cream containing 36 percent butterfat)

Whipping Temperature °F.	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c.c.
40	260	200	1.300	101	1.5
45	220	205	1.073	78	2.0
50	195	150	1.300	55	4.0
55	195	135	1.444	44	11.0
60	95	190	.500	36	24.0
65	5	240	.021	—	*

*Too soft for remaining on screen wire.

The effect of certain plant procedures for preparing whipping cream was studied. Table 2 and Figure 3 show that milk separated at 90° F. produced a slightly better whipping cream than milk separated at 100° F. Furthermore, the cream separated at 90° F. was higher in viscosity, which in itself is desirable from the sales standpoint. Data are not given to show the effect of separation temperatures in excess of 100° F. However, such temperatures are unsatisfactory because the viscosity of the cream is lowered as the separation temperature is increased and the whipping ability is also less desirable than at a lower temperature, such as 90° F. The practice frequently followed in small milk plants of skimming the milk not bottled directly after pasteurization, with or without some preliminary cooling, produces cream of low viscosity and a slightly impaired whipping ability. Separation of raw milk at about 90° F. then subsequent pasteurization of the cream is a more desirable procedure for whipping cream.

TABLE 2. EFFECT OF SEPARATION TEMPERATURE ON THE QUALITY OF WHIPPED CREAM

(Cream containing 35 percent butterfat)

Separation Temperature °F.	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c. c.	Relative Viscosity ° M No. 34 wire
90	250	165	1.515	87	7	148
100	215	185	1.162	96	8	120

Effect of Temperature on the Whipping Ability of Cream

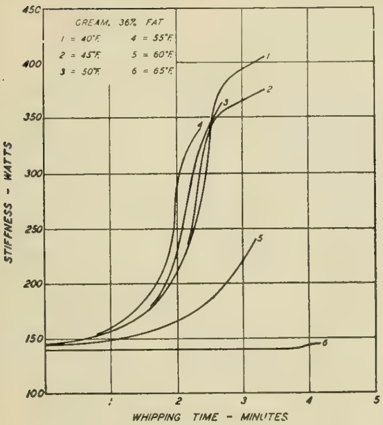


Fig. 2. Whipping Temperature

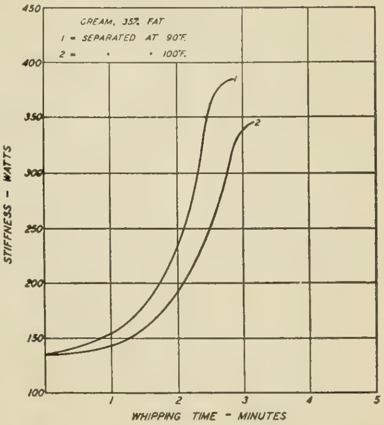


Fig. 3. Separation Temperature

The effect of the temperature of pasteurization was studied, with results shown in Table 3. In this experiment the cream was held for 30 minutes at the stated temperatures. There was a slight improvement in whipping ability at the higher pasteurization temperatures, but this improvement was not great enough to warrant the risk of damaging the flavor of the cream. The data in Table 3 do indicate that there is some basis for the practice followed by some dairymen of pre-heating cream to 160 to 165° F. before cooling to the usual holding temperature for pasteurization (145° F.). Evidently a slight improvement in whipping ability and a slight decrease in serum drainage are secured by this pre-heating method. Whether or not the extra effort is justified for the slight advantage is questionable.

Table 3. — Effect of Pasteurization Temperature on the Quality of Whipped Cream

(Cream containing 36 percent butterfat)

Pasteurization Temperature °F.	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c. c.
145	250	195	1.282	76	4
150	250	200	1.250	78	5
155	245	180	1.361	76	4
160	260	170	1.529	83	6
165	260	185	1.405	83	1

TABLE 4. — EFFECT OF THE STANDARDIZATION TREATMENT OF CREAM ON THE QUALITY OF WHIPPED CREAM

(Cream containing 45 percent butterfat was standardized to 30 percent butterfat.)

Standardization Treatment		Relative Viscosity Seconds	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c c	Percent Fat in Drain
Temperature °F.	Product Used							
Before Pasteurization:								
70	Whole milk	43.3	103	190	.542	126	25	0.7
70	Skim milk	42.4	101	180	.561	125	29	0.5
After Pasteurization:								
145	Whole milk	47.7	113	180	.628	131	27	0.4
95	Whole milk	48.9	111	180	.617	120	26	0.4
45	Whole milk	48.2	110	195	.564	115	25	0.3

TABLE 5. — EFFECT OF BUTTERFAT CONTENT AND AGING TIME ON THE QUALITY OF WHIPPED CREAM

Butterfat in Cream Percent	Relative Viscosity °M No. 34 wire	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c.c.
Aged 24 Hours						
20	60.5	85	230	.370	139	86
24.5	83	125	200	.625	127	54
29.5	103.5	190	175	1.086	116	31
34.5	184	245	150	1.633	94	10
39.5	271	285	130	2.192	83	0
Aged 48 Hours						
20	—	55	250	.220	133	89
24.5	—	150	240	.625	125	55
29.5	—	170	180	.944	116	32
34.5	—	235	150	1.633	87	8
39.5	—	280	130	2.154	86	0
Aged 72 Hours						
20	—	105	220	.477	145	83
24.5	—	160	225	.711	139	58
29.5	—	190	165	1.152	132	37
34.5	—	280	145	1.931	120	13
39.5	—	—	—	—	—	—

Standardization Methods, Fat Content and Aging Time

Reference to the data in Table 4 reveals that standardization of the cream with whole milk or skim milk, before or after pasteurization produced comparable results, regardless of the standardization procedure. The whipping time, the percentage of overrun, the amount of serum drainage, and the stiffness of the whipped cream remained virtually the same.

The influence of fat content and aging time was studied, with results given in Table 5 and Figure 4. Cream testing 41.5 percent fat was standardized to various percentages of fat as stated in the table. The results show that as the fat content of the cream was raised, the relative viscosity and stiffness were increased and the whipping time was decreased. The percentage of overrun and drainage decreased for the richer creams. Although the 39.5 percent cream whipped rapidly with no drainage at the end of 24 hours, still it was not a desirable whipping cream because of the low overrun and the excessive stiffness attained. This excessive stiffness produces a soggy or heavy whipped cream. The 20 percent and 24.5 percent creams had a very high overrun, but were

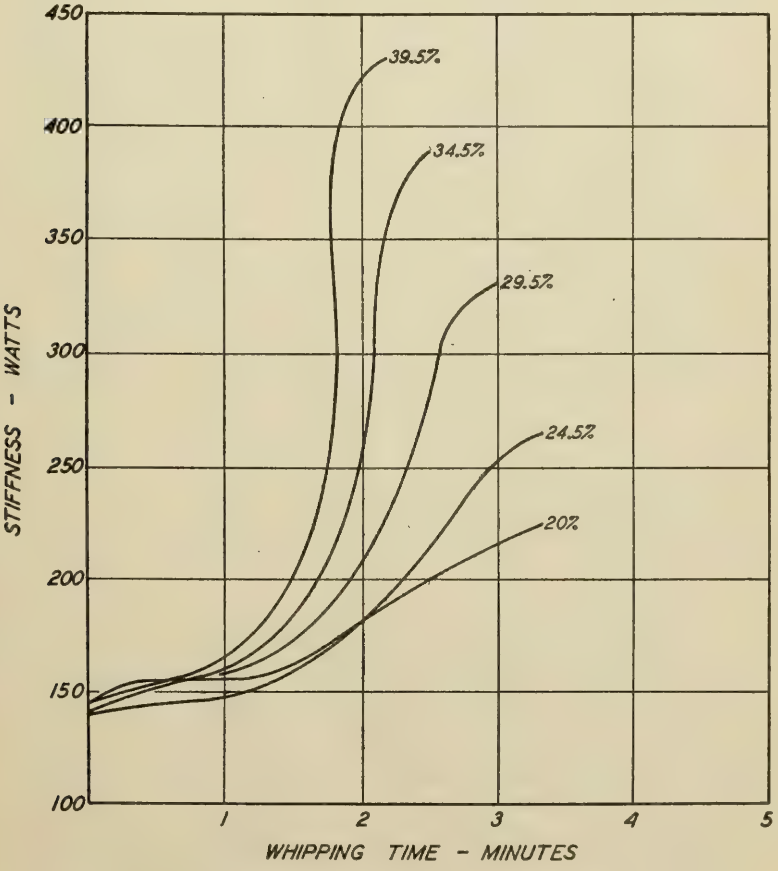


Fig. 4. Effect of Butterfat Content on the Whipping Ability of Cream

undesirable because they lacked stiffness and showed excessive drainage. From these results it appears that a cream testing from 30 to 34 percent fat is the most desirable for whipping.

Table 5 also shows the effect of 24-, 48-, and 72-hour aging periods. The rate of whipping and overrun was practically uniform for the 24-hour and 48-hour periods. Aging for 72 hours gave some improvement in whippinga bility and overrun over the 24-hour aging period. Serum drainage was practically uniform for all three aging periods. The advantages of the 72-hour aging period are not great enough to warrant its use. The dangers of bacterial increase and deterioration in flavor outweigh the slight advantages which result from 72-hour aging of the cream before whipping.

Effect of Added Colloids or Emulsifying Agents

Excessive serum drainage is a major defect of whipped cream. Although this defect can be practically eliminated by increasing the fat content of the cream, this method is not desirable for economic reasons. In this experiment various substances were added to cream, mainly to study their effect on serum drainage. The various products and the amounts in which they were used, together with the results obtained, are given in Table 6 and in Figures 5 to 11 inclusive. These materials were added to the cream before pasteurization. Since some of the substances did not readily dissolve in the cream, it was necessary to pasteurize at 160° F. in order to effect complete solution. A control was run for each substance used. In studying Table 6, comparisons should be made only within a group.

Only three of these materials, Dariloid, gelatin, and Vegetable Gelatin, increased the viscosity of the cream enough to be of any significance. Dehydrated egg albumin and egg yolk, Dariloid, and gelatin slightly decreased whipping ability, while Kraftogen had no noticeable effect. Sodium caseinate and Vegetable Gelatin slightly increased the whipping ability of the creams. All of the substances decreased the overrun except Kraftogen and sodium caseinate, neither of which had any marked effect. The serum drainage from the whipped cream after 24 hours was practically eliminated by the use of 0.4 percent Dariloid, 0.3 percent gelatin, and 0.4 percent Vegetable Gelatin, while the other substances had no marked effect. All of the materials had a tendency to decrease the percentage of fat in the drainage, except the egg yolk, which had no effect, and the egg albumin, which increased the loss of fat in the serum. None of the substances had any noticeable detrimental effect on the keeping quality of the whipped cream.

The only marked benefit obtained from the addition of the substances here studied was the elimination of serum drainage by the use of gelatin, Dariloid, and Vegetable Gelatin. This benefit was somewhat counteracted by a reduction in overrun and a reduction in whipping ability caused by gelatin and Dariloid. A small amount of serum drainage is not so undesirable when the cream is whipped by the housewife. However, serum drainage becomes of major importance in special uses for whipped cream, particularly when it is used for decorating purposes. Serum drainage also is of importance to the dairyman selling cream already whipped. Since the addition of foreign substances to whipping cream is not legal in many instances, the practice in general cannot be recommended.

TABLE 6. EFFECT OF ADDING VARIOUS SUBSTANCES TO CREAM ON THE QUALITY OF WHIPPED CREAM

(Cream containing approximately 30 percent butterfat)

Treatment of Cream	Relative Viscosity Seconds	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c.c.	Percent Fat in Drain
Dehydrated Egg Albumin							
None (control)...	53.1	115	175	.658	137	22	0.6
0.2 percent......	52.8	117	180	.657	130	23	.9
0.4 percent.....	53.5	117	190	.615	127	21	.9
0.6 percent......	53.5	109	190	.573	131	23	.9
Dehydrated Egg Yolk							
None (control)...	47.0	92	200	.460	131	31	.7
0.2 percent......	48.4	91	220	.413	121	31	.7
0.4 percent......	49.4	93	250	.372	121	31	.7
0.6 percent......	51.8	99	260	.380	120	31	.7
"Kraftogen"							
None (control)...	48.7	108	180	.600	127	25	.7
0.2 percent......	51.6	109	185	.589	124	23	.6
0.4 percent......	54.1	107	185	.578	125	24	.6
0.6 percent......	56.8	110	190	.579	125	22	.6
Dehydrated Sodium Caseinate							
None (control)...	50.5	96	190	.505	134	21	.7
0.2 percent......	52.9	100	190	.526	134	22	.7
0.4 percent......	55.4	100	180	.556	131	20	.6
0.6 percent......	59.9	107	185	.578	125	19	.6
"Dariloid"							
None (control)...	46.5	137	180	.761	135	23	.5
0.2 percent......	72.0	130	200	.650	125	18	.3
0.4 percent......	*	133	240	.554	108	2	—
0.6 percent......	*	92	180	.511	97	0	—
Gelatin (275 Bloom)							
None (control)...	51.2	142	160	.888	138	20	.7
0.2 percent......	89.1	120	175	.686	136	20	.3
0.3 percent......	223.6	127	210	.605	127	0	—
0.4 percent......	*	110	190	.579	124	0	—
"Vegetable Gelatin"							
None (control)...	48.1	115	195	.589	128	22	.7
0.2 percent......	*	130	240	.541	117	7	.5
0.4 percent......	*	144	235	.612	113	0	—
0.6 percent......	*	160	245	.653	109	0	—

*Too viscous for pipette.

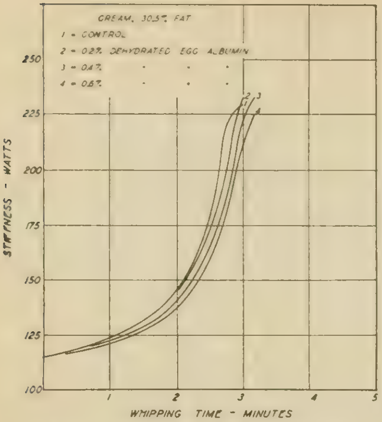


Fig. 5. Dehydrated Egg Albumin

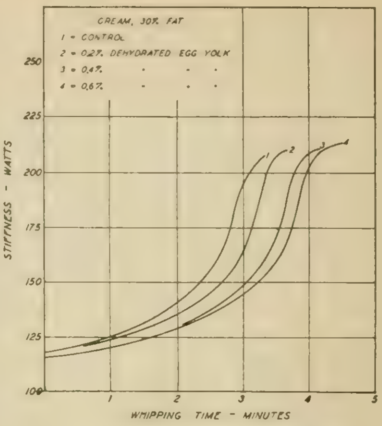


Fig. 6. Dehydrated Egg Yolk

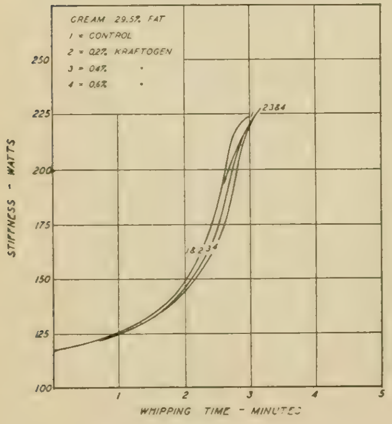


Fig. 7. Kraftogen

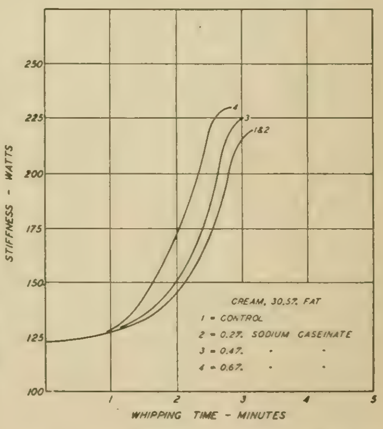


Fig. 8. Dehydrated Sodium Caseinate

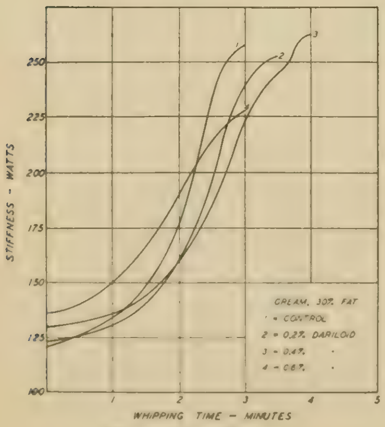


Fig. 9. Dariloid

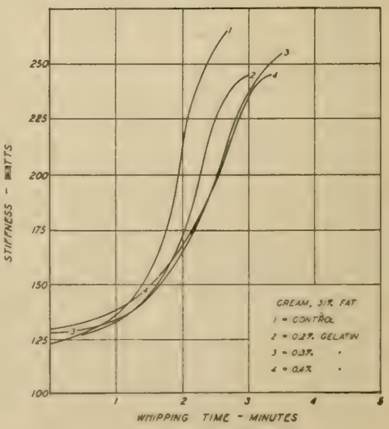


Fig. 10. Gelatin

Effect of Added Emulsifying Agents on the Whipping Ability of Cream

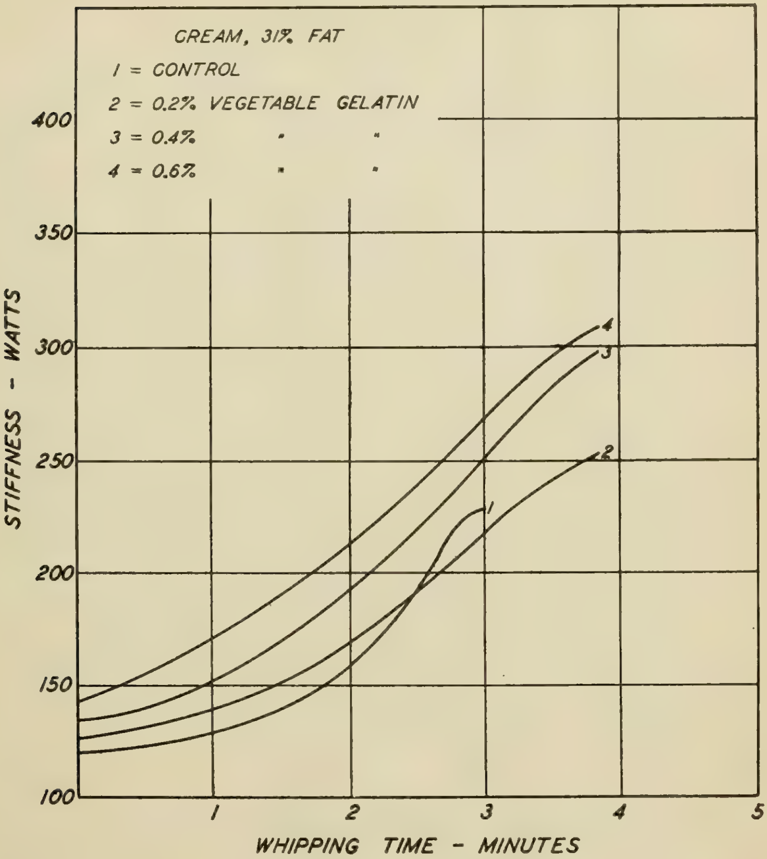


Fig. 11. Vegetable Gelatin

Effect of Increasing the Serum Solids

Other investigators have studied the effect of increasing the serum solids of cream by the addition of skim milk powder. Their findings are not in agreement. Mohr (4) found that increasing the serum solids content from 7 to 12 percent was not beneficial because it decreased whipping ability and increased drainage. Reid (3) reports that the increased serum solids content was beneficial.

In this experiment the natural serum solids content (6.3 percent) of 30 percent cream was increased to 11 percent by increments of 1 percent. Both skim milk powder and plain condensed skim milk were used for this purpose. They were added to the cream before pasteurization. The fat content remained constant at approximately 30 percent. The results of this study are given in Table 7 and in Figures 12 and 13. It will be noted that the viscosity of the cream increased with each increment of serum solids, and that condensed skim milk had more effect in this respect than powdered skim milk. Although raising

TABLE 7. — EFFECT OF INCREASING THE SERUM SOLIDS OF CREAM ON THE QUALITY OF WHIPPED CREAM

(Cream containing 30 percent butterfat)

SOURCE OF ADDED SERUM SOLIDS	Percent Serum Solids	Relative Viscosity Seconds	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Over-run Percent	Amount of Drain c.c.	Percent Fat in Drain
None added...........	6.3	46.2	101	180	.561	144	31	0.7
Skim Milk Powder...	7	49.5	101	190	.532	146	30	.6
	8	54.4	102	190	.537	141	29	.5
	9	59.6	103	190	.542	138	28	.5
	10	67.7	102	200	.510	134	27	.5
	11	76.2	102	210	.486	130	25	.5
None added...........	6.3	46.6	103	170	.606	138	27	0.5
Plain Condensed skim Milk.............	7	57.1	107	180	.594	132	24	.5
	8	68.7	112	190	.589	140	23	.5
	9	88.1	114	200	.570	132	20	.5
	10	123.2	121	210	.576	130	18	.5
	11	162.3	125	225	.556	128	14	.5

the serum solids with condensed skim milk increased the stiffness of the whipped cream, yet the average watt increase per second was slightly decreased because the whipping time was also increased. The addition of skim milk powder had no marked effect on the stiffness of the whipped cream. The additional serum solids slightly decreased the overrun and retarded drainage. These effects became more pronounced when the serum solids content reached 9 percent and over. Increasing the serum solids with skim milk powder slightly decreased the percentage of fat in the drainage, while the condensed skim mil had no definite effect on serum drainage.

These results indicate that the benefits derived by increasing the serum solids content of 30 percent cream to 11 percent are not great enough to justify the procedure.

Effect of Increasing Serum Solids on Whipping Ability of Cream

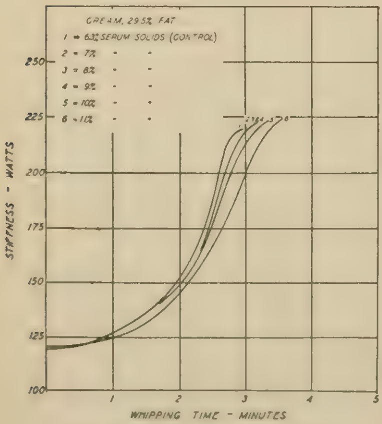


Fig. 12. Skim Milk Powder

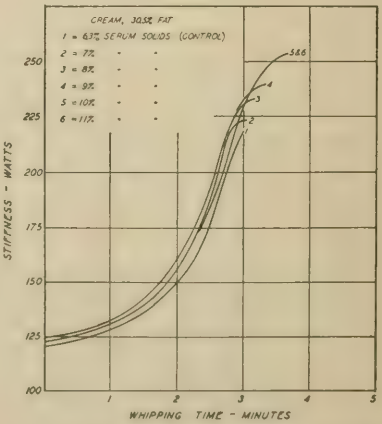


Fig. 13. Plain Condensed Skim Milk

Effect of Adding Sugar

Sugar is usually added to whipped cream in order to increase its palatability. The addition of sugar to whipping cream is an important factor which must be considered whenever cream is being whipped. It is difficult to determine the amount of sugar to add to whipped cream because personal preference varies so much. However, in this study the majority of people who tasted the sweetened whipped cream preferred that containing 10 percent sugar. The effect of time of adding 5, 10, and 15 percent of sugar was studied. The results are given in Table 8 and in Figure 14. It will be noted that the addition of sugar increased the serum drainage, reduced the overrun, and had no significant effect on the percentage of fat in the serum drainage. The time of adding the sugar had no effect on the amount of serum drainage, but did affect maximum stiffness, whipping time, and overrun. Before pasteurization and immediately before whipping were the least desirable times for adding the sugar from the standpoint of whipping ability. The former time was less desirable than the latter. When the sugar was added after one minute of whipping, the whipping ability was not impaired, the percentage of overrun was only slightly reduced, and the amount of drainage was only slightly increased. Practically the same results were obtained when the sugar was added after 1, 2, and 3 minutes of whipping. Increasing the amount of sugar magnified

TABLE 8. — EFFECT OF THE ADDITION OF CANE SUGAR ON THE QUALITY OF WHIPPED CREAM
(Cream containing 30 percent butterfat)

Time of Adding Sugar	Relative Viscosity Seconds	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c.c.	Percent Fat in Drain
5 Percent of Sugar Added							
None added (control)	48.9	108	175	.617	155	21	0.7
Before pasteurizing	53.1	101	190	.532	147	27	.6
Immediately before whipping	—	105	195	.538	150	27	.6
After whipping 1 minute	—	113	185	.611	152	25	.6
After whipping 2 minutes	—	115	180	.639	150	25	.6
After whipping 3 minutes	—	114	185	.616	151	25	.6
10 Percent of Sugar Added							
None added (control)	46	106	170	.624	124	22	.4
Before pasteurizing	54	107	260	.412	106	29	.4
Immediately before whipping	—	130	245	.531	105	30	.4
After whipping 1 minute	—	129	190	.679	115	31	.5
After whipping 2 minutes	—	125	185	.676	109	30	.4
After whipping 3 minutes	—	122	175	.697	107	27	.4
15 Percent of Sugar Added							
None added (control)	47.4	94	165	.570	127	28	.6
Before pasteurizing	61.2	83	300	.277	109	32	.8
Immediately before whipping	—	104	295	.353	112	35	.8
After whipping 1 minute	—	115	195	.590	113	37	.8
After whipping 2 minutes	—	110	185	.595	119	38	.8
After whipping 3 minutes	—	100	170	.588	114	37	.8

the effects; namely, a reduction in whipping ability and an increase in serum drainage.

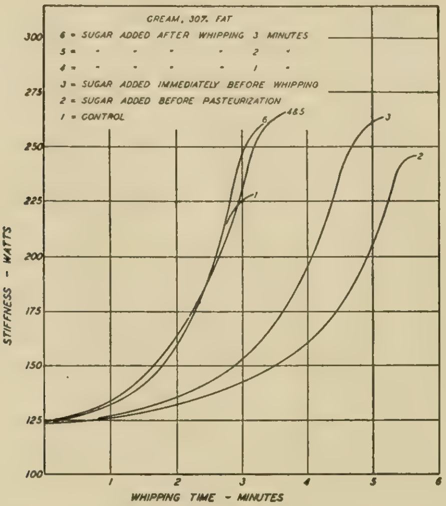


Fig. 14. Effect of Time of Adding Sugar on the Whipping Ability of Cream

The results obtained in this experiment show that 15 percent of sugar or less may be added any time after the first minute of whipping without any serious detrimental effects.

Table 9. — Effect of Homogenizing and Milling Cream on the Quality of Whipped Cream
(Cream containing 30 percent butterfat)

Treatment of Cream	Relative Viscosity Seconds	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c. c.	Percent Fat in Drain
Control	46.7	194	180	1.078	136	28	0.7
Homogenized:							
500 pounds pressure	81.6	179	460	.389	137	30	8.3
1,000 pounds pressure	*	127	420	.302	159	50	17.0
1,500 pounds pressure	*	265	440	.602	147	13	5.1
Milled	43.3	256	260	.985	130	28	1.4
Hand-homogenized	60.2	204	340	.600	151	35	6.3
Control	41.3	115	210	.548	127	36	0.6
Hand-homogenized once	51.3	96	480	.200	127	38	5.7
Hand-homogenized twice	64.2	102	630	.162	134	33	7.0

*Too viscous for pipette

Effect of Emulsification of Fat

In this experiment, cream was put through a homogenizer (commercial size), a colloid mill, and a hand homogenizer. The temperature of the cream was 145° F. for all the treatments. The homogenizer was a two-stage machine, but only one stage was used. The various treatments and the results are given in Table 9 and Figure 15. Comparisons should be made only within each group. It was found that homogenizing the cream at 500, 1000, and 1500 pounds pressure increased the viscosity, decreased whipping ability, increased overrun slightly, increased drainage except for the 1500 pounds pressure, and increased fat loss in drainage. The greater reduction in whipping ability for the 500 and 1000 pounds pressure when compared with 1500 pounds is probably due to the greater amount of fat clumping for the latter pressure. Milling the cream had no significant effect except for a definite increase of fat in the drainage. The hand homogenizer increased viscosity, was detrimental to whipping ability, and had no significant effect on overrun and amount of drainage. Like the other emulsifying machines it increased the percentage of fat in the drainage.

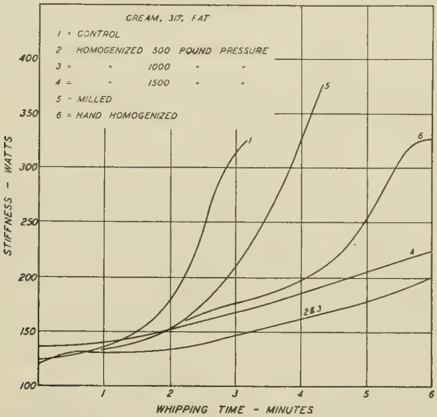


Fig. 15. Effect of Homogenization and Milling on the Whipping Ability of Cream

Effect of Temperature Treatments

For the first part of this study cream was cooled rapidly over a surface cooler after pasteurization to the following temperatures: 38°, 50°, 68°, 86° F. and 104° F.; held at these temperatures for 4 hours; and then rapidly cooled over the surface cooler to 40° F. and aged for 20 hours at this temperature. The results are given in Table 10 and Figure 16. They show no general beneficial effects from the use of various high initial aging temperatures. These results are in agreement with those obtained by Mohr (4); namely, that slow cooling of the cream had no beneficial effect on whipping ability.

The second part of this experiment consisted of a temperature treatment similar to Dahlberg's method for increasing the viscosity of cream (1). It differed in that no internal cooler was used and the cream was held for varying periods of time at 85° F. The cream was pasteurized in a 60-gallon, jacketed pasteurizer and cooled over a surface cooler (water and brine). The results

TABLE 10. — EFFECT OF TEMPERATURE TREATMENTS ON THE QUALITY OF WHIPPED CREAM
(Cream containing 30 percent butterfat)

Temperature Treatment	Relative Viscosity Seconds	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c. c.	Percent Fat in Drain
I. Effect of Delayed Cooling							
Cooled promptly (control)	43.0	104	175	.594	117	33	0.7
Before cooling, held 4 hrs.							
at 50° F.	42.3	111	195	.569	138	31	.7
68° F.	43.0	96	250	.384	120	26	.5
86° F.	42.0	101	215	.470	113	29	.5
104° F.	42.5	105	205	.512	121	31	.6
II. Effect of Dahlberg's Method for Increasing the Viscosity of Cream*							
Not reheated (control)	41.3	118	200	.590	133	34	.6
Reheated and							
Recooled promptly	41.9	128	235	.545	133	33	.7
Held for 15 minutes	42.2	123	230	.535	135	37	.8
Held for 30 minutes	42.0	109	230	.474	122	36	.7
Held for 60 minutes	42.8	110	240	.458	129	30	.7

*Used surface cooler instead of internal tubular cooler.

are given in Table 10 and in Figure 17. Reheating the cream and recooling it quickly increased very slightly both the viscosity and the stiffness of the whipped cream. However, the cream so treated whipped more slowly than the control. Holding the reheated cream for over 15 minutes at 85° F. resulted in a further reduction in whipping properties.

Effect of Temperature Treatments on the Whipping Ability of Cream

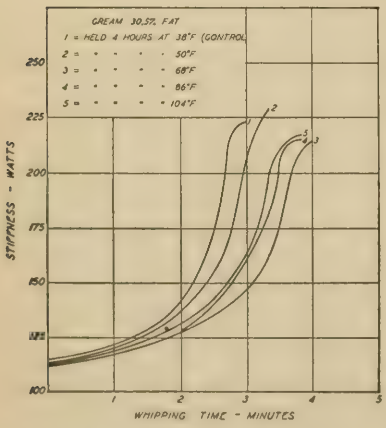


Fig. 16. Delayed Cooling

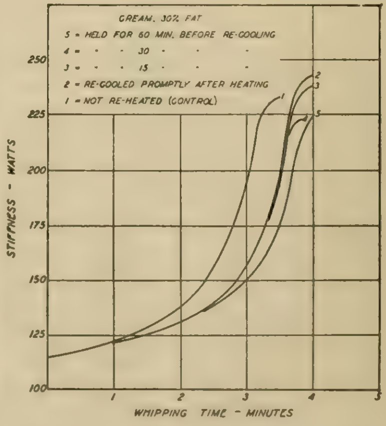


Fig. 17. Dahlberg's Method for Increasing Viscosity

Reconstituted Cream

Reconstituted cream, testing 30.5 percent fat, was made by mixing sweet butter and skim milk with a hand homogenizer. The butter and skim milk were pasteurized together at 145° F. for 30 minutes and homogenized at the temperature of pasteurization. This cream was compared with ordinary cream of the same fat content, which was not homogenized. The results are given in Table 11 and Figure 18. Reconstituted cream was not equal to ordinary cream in whipping properties. The overrun and viscosity were greater for the reconstituted cream. There was little difference in the amount of drainage, but the fat loss in the drainage was much greater for the reconstituted cream. Furthermore, the flavor of the whipped reconstituted cream was inferior to that of the normal cream.

TABLE 11. — THE QUALITY OF WHIPPED CREAM MADE FROM RECONSTITUTED CREAM

(Cream containing 30.5 percent butterfat)

Treatment of Cream	Relative Viscosity Seconds	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c.c.	Percent Fat in Drain
Reconstituted cream	73.4	80	280	.286	195	31	3.2
Control, not homogenized	49	110	170	.647	134	27	.4

Effect of Freezing Milk Prior to Separation and of Freezing Cream

Sometimes whipping cream which has been partly or totally frozen is put on the market. In sections of the country where the winters are severe, whipping cream may have been frozen under various natural conditions. For instance, the milk may freeze prior to separation or the cream may freeze while in the hands of the producer or in transit. The whipping cream may also freeze after being processed, while standing on the customer's door-step. Even in sections where the winters are not so severe, customers may receive whipping cream which has been frozen, because cream can now be successfully stored in a frozen state and delivered as such to wholesale buyers.

Although it is generally known that the total freezing of cream destroys its whipping properties, yet very little experimental work has been reported on the effects of partial freezing of cream and the time of freezing. Baldwin and Combs (6) studied the effect of partial freezing of milk prior to separation and of partial and total freezing of cream upon the ultimate whipping properties of such cream. However, they did not study the effect of time of freezing, whether before or after pasteurization. These investigators used a hand-operated whipper and no provision was made for determining the stiffness of the cream during the whipping process.

In this study cream obtained from partly frozen milk was whipped, as well as partly and totally frozen cream. The effects of the time of freezing on the whipping properties were also studied. A 20-gallon batch of raw, mixed herd milk which had been cooled to 40° F. was equally divided. One portion was

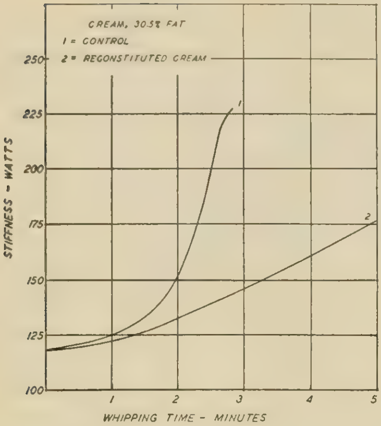


Fig. 18. Whipping Ability of Reconstituted Cream

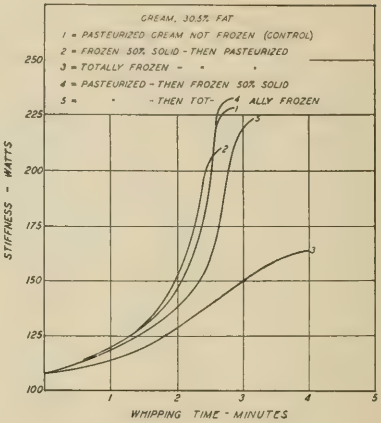


Fig. 19. The Effect of Freezing on the Whipping Ability of Cream

set in a room maintained at 0° to –10° F. The other portion, which served as the control, was held at 38° F. When 13 percent of the milk was frozen solid it was thawed by running hot water, approximately 155° F., down the sides of the can. Immediately after thawing, both the control and the experimental batch were heated to 92° F. and separated with a hand-power separator. The resulting cream was standardized to 30 percent fat with the skim milk from which the cream was taken. The cream was pasteurized, cooled, and whipped according to the standard procedure for this study.

The results obtained are given in Table 12, and show that freezing 13 percent of the milk prior to separation has no marked effect on the whipping properties of the resulting cream.

TABLE 12. — EFFECT OF FREEZING MILK AND CREAM ON THE QUALITY OF WHIPPED CREAM

(Cream containing 30 percent butterfat)

Treatment	Relative Viscosity Seconds	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c. c.	Percent Fat in Drain
Raw milk not frozen (control)	40.6	83	260	.319	112	35	1.1
Raw milk partly frozen (13%)	40.5	87	260	.335	110	33	1.1
Pasteurized cream not frozen (control)	44.6	118	180	.655	142	40	.9
Cream frozen before pasteurizing							
50% solid	43.4	101	160	.631	132	43	1.3
Totally	37.9	47	255	.185	97	70	1.0
Cream frozen after pasteurizing							
50% solid	46.3	118	185	.638	126	42	.8
Totally	51.6	104	210	.495	113	47	.7

In the frozen cream studies a batch of cream was prepared according to the standard procedure as given under experimental methods. Immediately after standardization the cream was given the following treatments:

1. Control — pasteurized cream, not frozen.
2. Frozen 50 percent solid, then pasteurized.
3. Totally frozen, then pasteurized.
4. Pasteurized, then frozen 50 percent solid.
5. Pasteurized, then totally frozen.

The cream was frozen in one-gallon ice cream cans placed in brine at approximately 0° F. Immediately after freezing, the cream was thawed slowly by placing the cans in a water bath at 70° F. It was then pasteurized, cooled, aged, and whipped according to standard procedure.

The results are given in Table 12 and Figure 19. Freezing cream 50 percent solid, either before or after pasteurization, had no significant effect on the whipping qualities of the cream. Total freezing of cream before pasteurization destroyed the whipping properties of the cream, while total freezing of the cream after pasteurization was only slightly detrimental to the whipping properties. The results on the effect of partly frozen milk as well as those obtained with cream frozen before pasteurization are in close agreement with those obtained by Baldwin and Combs (6).

These results have a practical significance because they indicate that if the cream should be totally frozen while in the hands of the producer, most of the whipping properties would be destroyed. If the cream should be frozen after it has been processed, for instance while standing on the customer's doorstep, then the whipping properties would be only slightly damaged.

Effect of Feed

The Animal Husbandry Department of this station conducted an investigation in which tankage was compared with a soybean – cottonseed ration for milk production. Since the theoretical explanation of cream whipping is concerned with the protein membrane surrounding the fat globules, it seemed desirable to check the whipping ability of the cream produced while the two sources of protein were being compared. The entire production of each group of twelve cows for one milking was kept separate on two occasions, and a representative portion of each lot was separated and standardized to 32 percent fat. The cream was whipped and the results are given in Table 13. The results show that the source of food protein, namely animal and vegetable, had no significant effect on the whipping ability of the cream.

TABLE 13. — EFFECT OF FEED ON THE QUALITY OF WHIPPED CREAM

(Cream containing 32 percent butterfat)

Source of Protein	Relative Viscosity Seconds	Increase in Stiffness Watts	Whipping Time Seconds	Average Watt Increase per Second	Overrun Percent	Amount of Drain c. c.	Percent Fat in Drain
Vegetable protein	48.3	62	225	.273	112	41	0.5
Animal protein	51.3	62	230	.270	108	37	.5

SUMMARY

A mechanical whipper of constant speed was used for whipping the cream. Relative stiffness of the whipped cream was determined by measuring with a sensitive wattmeter the input of the whipper motor in watts at intervals of five or ten seconds throughout the whipping process. The relative whipping ability of the cream was determined by comparing the average watt increase in stiffness per second of whipping time. Other properties studied were viscosity, overrun, and serum drainage.

Increasing the whipping temperature of a 36 percent cream above 40° F. reduced the maximum stiffness and the overrun and increased the serum drainage of the whipped cream.

Milk separated at 90° F. produced a slightly better whipping cream than milk separated at 100° F.

Time of standardization, whether before or after pasteurization, had no noticeable effect on whipping. Skim milk and whole milk were compared for standardizing 45 percent cream to 30 percent. No significant differences were noted in the whipping ability of the resulting cream.

Variation in pasteurization temperatures from 145° F. to 165° F. had little effect on whipping ability.

There is no practical advantage in aging whipping cream longer than 24 hours.

Cream containing 30 percent butterfat is satisfactory for whipping.

The following substances in varying amounts up to 0.6 percent were added to cream before pasteurization: Kraftogen, dehydrated sodium caseinate, Dariloid, gelatin, Vegetable Gelatin, dehydrated egg albumin, and dehydrated egg yolk. Only Dariloid, gelatin, and Vegetable Gelatin increased the viscosity of the cream enough to be of any significance. The whipping ability of the cream was slightly increased by sodium caseinate and Vegetable Gelatin and slightly decreased by the other substances. The overrun was decreased by all of these products except Kraftogen and sodium caseinate, which had no marked effect. The serum drainage from the whipped cream that had stood for 24 hours was practically eliminated by the use of 0.4 percent Dariloid, 0.3 percent gelatin, or 0.4 percent Vegetable Gelatin, while the other substances had no noticeable effect. The percentage of fat in the drainage was decreased by all the substances except the egg yolk, which had no effect, and the egg albumin, which increased the loss of fat in the serum. In conclusion, the only marked benefit obtained from the addition of the various substances here studied was the elimination of serum drainage by the use of gelatin, Dariloid, and Vegetable Gelatin. However, this benefit was somewhat counteracted by a reduction in overrun, and a reduction in whipping ability in the case of gelatin and Dariloid. Since the addition of foreign substances to whipping cream is not legal in many places, the practice in general cannot be recommended.

Increasing the percentage of serum solids from 6.3 to 11 percent at 1 percent intervals by the use of skim milk powder and plain condensed skim milk slightly decreased the whipping ability and the serum drainage. The viscosity of the cream increased as the serum solids content was raised, and the plain condensed skim milk was more effective than the powdered skim milk in this respect. The benefits derived from increasing the serum solids content of 30 percent cream to 11 percent were not great enough to justify the procedure.

The addition of 10 percent cane sugar appeared to give sufficient sweetness to the whipped cream. Before pasteurization and immediately before whipping are the least desirable times for adding the sugar. Sugar up to 15 percent may be added any time after the first minute of whipping without any appreciable detrimental effects.

Homogenization (500 to 1500 pounds pressure), milling, and hand homogenization produced no beneficial effects on the whipping ability of cream.

Delayed cooling of cream after pasteurization, when the time and temperature were carefully controlled, was found to be of no benefit to whipping cream.

Reconstituted cream made by mixing butter and skim milk with a hand homogenizer did not compare favorably with ordinary cream in whipping ability or flavor.

The source of protein in the feed, whether vegetable or animal, had no effect on the whipping ability of the cream.

Partial freezing (13 percent) of the milk prior to separation had no marked effect on the whipping properties of the resulting cream.

Partial freezing of the cream (50 percent solid) either before or after pasteurization had no significant effect on the whipping qualities of the cream.

Total freezing of the cream before pasteurization destroyed the whipping properties of the cream, while total freezing of the cream after pasteurization was only slightly detrimental.

REFERENCES

(1) Hening, J. C., and Dahlberg, A. C. A temperature treatment for increasing the viscosity of sweet cream. N. Y. State Agr. Expt. Sta. Tech. Bul. 197, 1932.

(2) Templeton, H. L., and Sommer, H. H. Studies on whipping cream. Part I, Jour. Dairy Sci. 16:329. 1933;
Part II, Jour. Dairy Sci. 17:307. 1934.

(3) Mueller, W. S. A method for the determination of the relative stiffness of cream during the whipping process. Jour. Dairy Sci. 18:177–180. 1935.

(4) Mohr, W. A study on whipping cream. Molk. Ztg. (Hildesheim) 39:259. 1925.

(5) Reid, W. H. E., and Eckles, W. C. The manufacture of whipped cream using dry skim milk. Mo. Agr. Expt. Sta. Circ. 180, 1934.

(6) Baldwin, F. B., Jr., and Combs, W. B. Whipping properties of cream as influenced by freezing and thawing. Milk Plant Monthly 22 (No. 1): 18. 1933.

Publication of this Document Approved by Commission on Administration and Finance
5m. 2-'37. No. 9783.

14b
3
336

[illegible]
CULTURAL BRANCH LIBRARY
BLACKSBURG, VIRGINIA
12/11/[illegible]

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 336 November, 1936

Apple Cider and Cider Products

By J. A. Clague and C. R. Fellers

Greater care in the application of approved known methods in the production and preservation of apple cider and cider products should make for an enlarged demand for these popular by-products of the fruit industry. This bulletin gives the results of investigations in this field.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

APPLE CIDER AND CIDER PRODUCTS

By J. A. Clague, Assistant Professor, and C. R. Fellers, Research Professor, in Horticultural Manufactures

Production of year-round marketable cider from apples which are below market grade has long been the hope of the apple growers of this country. However, as yet no preserved sweet cider beverage has attained the popularity prophesied for it at the time of its innovation. Some of the reasons for such a condition are: (1) Insufficient care in selection and blending of varieties. (2) Use of immature and unripe fruit; that is, apples picked at the same time as those intended for market and then culled out, rather than tree-ripened fruit. (3) Faulty manufacturing practices due to lack of technical knowledge about the processing and preservation of apple cider.

To present information gathered from experiments on several varieties of Massachusetts apples as well as work done by investigators in other states and countries is the object of this bulletin. It is hoped that the information presented will answer many of the questions confronting fruit growers and others when they consider the manufacture of cider.

COMPOSITION OF THE MORE IMPORTANT MASSACHUSETTS APPLE VARIETIES[1]

In this country cider-making quality is not ordinarily considered in the selection of apple varieties for the orchard. In many of the European countries the growing of apples especially for manufacture into cider has been practiced for hundreds of years. This is one reason why in England, for example, the annual consumption of cider is two gallons per capita, while in this country it is not much over one quart per capita.

However, it should be noted that in England the term cider denotes a fermented, usually carbonated or sparkling, apple juice, while in this country cider refers to the unfermented juice unless preceded by the term "hard." An apple variety which might make a good sweet cider would not necessarily be satisfactory for manufacture into sparkling cider, although Davis (12) found that the Baldwin made a good sparkling cider, and here it has proved to be one of the best for sweet cider.

It is generally conceded that the Russet apple is the best single variety for manufacture into cider. However, by judicious blending of cider from two or more varieties, a product can often be made which is better than the juice from any one variety.

This laboratory has rated cider made from some of the more important Massachusetts apples as follows: 1. Roxbury Russet. 2. Baldwin. 3. Northern Spy. 4. Rhode Island Greening. 5. McIntosh. 6. Ben Davis. 7. King. 8. Wealthy.

The more important physical and chemical characteristics of the ciders listed above were determined during the seasons of 1933 and 1934. Crab-apple cider was also analyzed in 1933. The results obtained, which are shown in Table 1, should be an important aid in the blending of ciders as well as giving a comparison of the composition of a good cider apple such as Russet with that of a poor one such as Wealthy.

---

[1] Many of the analytical results presented in this section are taken from the master's thesis of Eunice M. Doerpholz, Mass. State College, 1935.

Specific Gravity

The determination of specific gravity was made using a hydrometer at a temperature of 21° C. (70° F.). The figure given in the table represents the number of times heavier the cider is than an equal volume of water when both are measured at a standard temperature. Specific gravity may be used as an approximate method of determining the amount of alcohol formed during the fermentation of cider. A nine-point drop on the hydrometer scale is equal to approximately 1 percent of alcohol by volume, so that a sweet cider with a specfic gravity of 1.050 at the start of the fermentation would have to be fermented to 1.041 to get a 1 percent alcoholic content by volume.

As will be seen from Table 1, the highest specific gravity was found in the Russet and crab-apple ciders, the lowest in the McIntosh and Wealthy ciders.

Degrees Brix

The Balling or Brix test indicates roughly the percentage of sugar in the juice, or, more exactly, the concentration of a sucrose solution of the same density as the juice being tested.

The determination was made with a hydrometer of the same type as that used for the specific gravity determination, the difference being that the Brix hydrometer has a scale calibrated in degrees from 0° to 30° or 30° to 60°, depending on the sugar concentration of the liquid to be measured. The actual sugar content is usually 1.5 to 2 percent less than the degrees Brix as this reading is influenced by other soluble solid material in the juice such as minerals, acids, pectin, proteins, etc. However, the determination is very simple and rapid and is one that any cider manufacturer will find helpful. The Russet and crab-apple ciders had the highest Brix reading of all the varieties tested.

The Brix reading may also be used to estimate the percentage of alcohol formed during fermentation. A decrease of one degree on the Brix scale indicates that approximately one half of one percent by weight (0.5%) of alcohol has been formed. For example, if the Brix reading was 12° at the start of the fermentation and if at the end of a week the reading had dropped to 6°, the alcohol content of the cider would be roughly 3 percent.

pH Determination

Measurement of pH was made with a quinhydrone electrode during the 1934 season and by the colorimetric method during the 1933 season. This determination is not one that the average cider maker will use, but the pH value is an important factor to be considered in blending ciders. The reason for this is that two ciders might have the same total acid content but because of other constituents in the juice, the "active" acidity or pH might be different. It is the "active" acidity which determines the relative sourness or acid taste of a product. A low pH value indicates a high degree of "active" acidity and vice versa

The results in Table 1 indicate that the pH varies somewhat from season to season and that there is also considerable difference between varieties. Of the ciders made during the 1933 season McIntosh had the lowest pH and Ben Davis and King the highest. Cider from the two latter varieties also had the highest pH in 1934, while Russet and Wealthy had the lowest.

TABLE 1. COMPOSITION OF CIDERS MADE FROM SEVERAL VARIETIES OF MASSACHUSETTS APPLES

VARIETY	Specific Gravity		Degrees Brix		pH		Viscosity		Pectin Percent		Tannin Percent		Total Acid Percent		Ash Percent	
	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934	1933	1934
Baldwin	1.055	1.041	14.1	11.8	3.2	3.5	3.8	3.2	.10	.10	.08	.06	.56	.48	.16	.19
Ben Davis	1.045	1.045	10.9	11.5	4.0	3.7	4.2	3.8	.08	.31	.05	.06	.33	.43	.20	.16
King	1.055	1.050	12.5	12.9	4.0	3.6	5.1	7.3	.18	.26	.04	.07	.40	.53	.16	.17
McIntosh	1.045	1.040	12.2	11.5	3.1	3.5	4.3	4.6	.18	.11	—	.08	.41	.48	.24	.15
Northern Spy	1.045	1.045	11.8	12.0	3.2	3.4	4.0	2.2	.08	.09	.08	.08	.48	.49	.18	.13
Rhode Island Greening	1.045	1.045	11.2	12.0	3.2	3.5	4.7	5.6	.16	.30	.04	.07	.44	.47	.14	.12
Roxbury Russet	1.065	1.065	15.5	16.0	3.9	3.3	5.1	4.7	.18	.32	.07	.06	.61	.67	.15	.15
Wealthy	1.040	1.045	9.8	11.5	3.6	3.3	4.7	4.2	.15	.28	.05	.05	.57	.61	.23	.19
Crab	1.065	—	16.0	—	—	—	—	—	.09	—	.25	—	.75	—	.38	—
Average	1.051	1.047	12.7	12.4	3.5	3.5	4.5	4.5	.13	.22	.08	.07	.51	.52	.20	.16

Viscosity

The ratio of the rate of flow of cider to the rate of flow of water is a measure of viscosity. The determination must be made at a given temperature in order to have the results comparative. In this study, the time required for cider to pass between two marks on a pipette, divided by the time for the same volume of water to pass between the marks—is the value given as the viscosity. The higher the viscosity, the more "body" the juice will have. The body can be determined approximately by the "feel" of the cider in the mouth, but the method described above gives a more definite basis of comparison.

Viscosity will vary with the quality of the fruit. A hard, ripe fruit usually yields a cider with a low viscosity, while cider made from fruit of the same picking after storage of several months will have a very high viscosity. As the cells break down during storage, the pectin, one of the constituents causing a high viscosity, is more readily extracted with the fruit juice and results in a cider of high viscosity. Because freezing also tends to break the cell walls, cider made from apples which were frozen and subsequently thawed is very oily in consistency and has a high viscosity.

Pectin

The alcohol precipitate method as recommended by the A.O.A.C. (1) was used to determine the pectin content of the ciders. As has been mentioned in the previous section, it is the pectin which is the factor responsible for the "body" of a cider and the pectin content of the apple juice depends to a large extent upon the condition of the fruit at the time of pressing. Although apples are rich in pectin, the amount found in cider is low because the juice is cold pressed and pectin is only sparingly soluble in cold fruit juices. The lowest pectin content in the ciders examined was 0.08 percent in the Northern Spy and Ben Davis ciders made in 1933; the highest was in the Russet cider made in 1934.

Tannin and Coloring Matter

To determine the exact amount of tannin in a fruit juice would require a very involved procedure. Hence, the method commonly used for the determination of tannin is by titration with a standard potassium permanganate solution using indigo carmine solution as an indicator. Because the potassium permanganate reacts with the coloring matter in the ciders as well as with the tannin, the value obtained is designated as "tannin and coloring matter". The method is given in detail by the A.O.A.C. (1).

Tannin is an important constituent of apple cider in that it contributes the astringent taste which gives so much character to a good cider. Crab-apple cider had the highest tannin content, 0.25 percent, of any of the varieties tested, as might be expected from the astringent taste of the crab-apple. The other ciders had less than one-third the tannin content of the crab-apple, the maximum being 0.08 percent in the Northern Spy, McIntosh and Baldwin.

Total Acid

This determination was made by diluting 10 cc. of the cider with 100 c.c of distilled water, bringing the solution to a boil, cooling and titrating with 0.1 normal sodium hydroxide solution, using phenolphthalein as an indicator.

Crab-apple cider was found to have the highest total acid content, 0.75 percent. Russet was next with a content of 0.61 percent in 1933 and 0.67 percent in 1934. Acidity was calculated as malic acid.

Ash

From the standpoint of taste and flavor, the ash content of a cider is of little significance. The chief value of an ash analysis is as an indication of the mineral content of the product analyzed.

The determination was made by evaporating 25 grams of cider down to dryness in an electric oven and then burning it to an ash in a muffle furnace at a temperature of 700°–800° C. (1292°—1472° F.). By weighing the empty container before the cider is put into it and the same container with the ash in it, the percentage of ash can be calculated.

The ash content of the ciders compared favorably with that found in the whole apple. Sherman (23) gives 0.176 as the ash content of apples and in this investigation the ash content varied from 0.12 to 0.38 percent, crab-apple cider having the highest value.

Discussion

Most of the ciders varied in composition from one season to the next. There are so many factors which might be the cause of this variation that it is not feasible to discuss all of them here. Shaw (22) and Caldwell (3, 4, 5, 6,) have shown the effect of climatic and other conditions on the composition of apples and apple juices.

It is interesting to note the composition of the Russet cider, as it was found to be the best for drinking purposes. This cider was higher in sugar content than any of the other ciders tested, with the exception of the crab-apple cider, during both the 1933 and 1934 seasons, and also had the highest total acid content and a fairly high tannin content to give the right "tang" to the juice. The Wealthy cider, on the other hand, had a fairly high acid content, but was low in sugar and tannin. From the standpoint of palatability, this cider was the least desirable of any made in this study.

BLENDING

It is not possible to give any rule for blending ciders that will prove infallible. The most important factors to be considered are the degrees Brix, the tannin content, the pH, and the total acidity.

According to Charley (9), English cider apples are put into three classifications as follows:

1. **Sharp juices** with a malic acid content greater than 0.45 percent.
2. **Sweet juices** with a malic acid content less than 0.45 percent, and with a tannin content less than 0.2 percent.
3. **Bittersweet juices** with a malic acid content less than 0.45 percent, and with a tannin content greater than 0.2 percent.

This classification does not take into account the sugar content of the apples since English cider apples are used chiefly for making a fermented beverage. However, the sugar content of the cider apples is given as 12.5 percent, so on the basis of the grouping shown above, most of the ciders studied in this investigation would be classed as sweet juices.

Since none of the common dessert apples have a high tannin content, and since the so-called bittersweet cider apple is not grown to any extent in this country, the crab-apple would probably have to be used in blending to supply astringency as it has a tannin content of 0.25 percent. Caldwell (5) has shown that French cider varieties are adaptable to conditions in this country and are desirable for blending with American dessert varieties.

For the benefit of those who might wish to blend ciders with more accuracy than is possible by taste or flavor, the method of Pearson's Square is given.

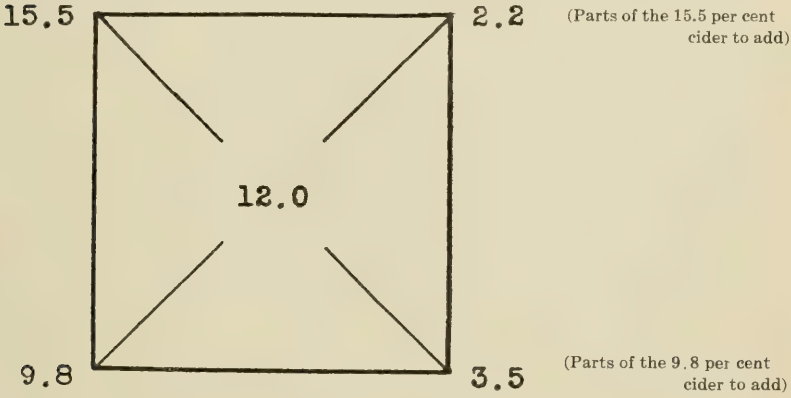

15.5
2.2
(Parts of the 15.5 per cent cider to add)
12.0
9.8
3.5
(Parts of the 9.8 per cent cider to add)

Figure 1. Pearson's Square

The procedure in using the square is best illustrated with an example If a cider containing 12 percent sugar is desired as the finished product, the figure 12 is put in the center of the square, as illustrated in Figure 1. The two ciders available are, say, a 15.5 percent cider and a 9.8 percent cider. Then the figure 15.5 is put in the upper left-hand corner and the figure 9.8 in the lower left-hand corner. The results obtained by substracting the figures in the corners from the center figure (always subtracting the less from the greater) are placed diagonally opposite from the original figure on the right-hand side. In the example given, 12 would be subtracted from 15.5 giving 3.5 as the result, and 9.8 would be subtracted from 12 giving a result of 2.2. So, to get a cider with a sugar content of 12.0 percent, 2.2 parts of the 15.5 percent cider should be mixed with 3.5 parts of the 9.8 percent cider. "Parts" may refer to quarts, gallons, or barrels of cider depending on the quantity at hand, or the method of measuring available. It would not be possible to use the method for calculating the amount of dry sugar to add without making other allowances. Pearson's Square may also be used in the manner given above for adjusting the acid or tannin content of ciders by blending. It is also a convenient tool for adjusting the acid content of vinegar.

PRESSING

According to Chenoweth (11) the yield of cider depends principally upon four factors:

1. The variety of apple.
2. The condition of the fruit.
3. The type of equipment.
4. The method of manipulation.

Yields of cider obtained from several varieties of apples pressed at different seasons of the year are shown in Table 2. Pressings were all made on a power press so that variations in the yield of cider caused by the type of equipment and method of manipulation were reduced to a minimum.

The highest yield of cider, 4.4 gallons per bushel, was obtained from Baldwin apples pressed in October. The lowest yield, 2.4 gallons per bushel, was obtained from Russet apples pressed in April.

TABLE 2. EFFECT OF VARIETY AND DATE OF PRESSING ON THE YIELD OF CIDER

VARIETY	Date of Pressing	Weight of Apples Pounds	Weight of Cider Pounds	Gallons of Cider	Yield per 50 lb. bushel Gallons
Baldwin	Oct. 11, '34	85.5	66.5	7.6	4.4
	Jan. 15, '35	88	60.5	7.0	4.0
	Apr. 3, '35	126.5	79	9.1	3.6
	Mar. 2, '36	155.5	88.5	10.2	3.3
Average					3.8
Ben Davis	Jan. 15, '35	84	43.3	4.9	2.9
	Mar. 11, '35	84	38.5	4.4	2.6
	Mar. 2, '36	186.5	95.7	11.0	2.9
Average					2.8
King	Nov. 3, '34	86	48.5	5.6	3.3
	Jan. 15, '35	90	50	5.7	3.2
	Nov. 25, '35	93	61.8	7.1	3.8
	Jan. 23, '36	79	40.5	4.7	3.0
Average					3.3
McIntosh	Oct. 11, '34	82.5	58.5	6.7	4.0
	Oct. 25, '34	83.0	52.0	6.0	3.9
	Nov. 6, '34	42.0	25.	2.9	3.5
	Mar. 11, '35	91.5	50	5.7	3.1
	Nov. 25, '35	93	61.8	7.1	3.8
	Jan. 23, '36	81	45	5.1	3.1
Average					3.6
Northern Spy	Nov. 27, '34	91	57	6.6	3.6
	Apr. 3, '35	127.5	67.5	7.8	3.1
	Jan. 23, '36	126	87.5	10.1	4.0
	Mar. 2, '36	78.5	44.5	5.1	3.2
Average					3.5
R. I. G.	Oct. 11, '34	40	26	3	3.8
	Nov. 27, '34	94	58	6.7	3.6
	Apr. 3, '35	138.5	76	8.7	3.1
	Jan. 23, '36	100	66.5	7.6	3.8
Average					3.6
Russet	Nov. 27, '34	88	52.5	6.0	3.4
	Apr. 3, '35	120	50	5.7	2.4
	Jan. 23, '36	112	68.5	7.9	3.5
	Mar. 2, '36	68.5	46.5	5.3	3.9
Average					3.3
Crabapple	Nov. 25, '35	88	50.5	5.8	3.3

It should be noted, however, that the next year Russet apples gave a yield of 3.9 gallons to the bushel when pressed in March, the highest yield of any variety pressed at that time of year. Ben Davis apples gave the lowest average yield, but the pressings were all made late in the season so that the figures do not give a true indication of the yield which might be obtained in the fall of the year.

Baldwin, Russet, Northern Spy, Rhode Island Greening, and McIntosh all retained their cider-making qualities well into the February following the autumn they were picked, when they were held under good storage conditions. Aside from the increased yield obtained when sound, ripe fruit is used, the aroma and quality of the cider is also a factor to be considered.

Type of Equipment

Manufacturers of cider-making equipment have various types of mills from small hand mills with a capacity of 60 to 90 gallons a day to large power mills capable of producing more than 6,000 gallons of cider in a 10-hour day.

Although formerly the less efficient hoop or barrel type of press was used in the hand mills, now the rack and cloth press is standard equipment for practically all the mills.

Method of Manipulation

Increased yields of cider may be obtained by proper care in grating the fruit, building the cheese and applying the pressure. The grater type of pulper is better than the crusher for grinding the fruit. Grinders as supplied by the manufacturers are usually efficient.

The layers of the cheese should be of uniform thickness equal to the depth of cheese frame. The pulp must be packed into all corners and should be of the same density throughout to insure uniform pressure. The pressure should be applied slowly and should be maintained for at least 10 minutes at the maximum pressure.

A deeper-colored cider and a higher yield can also be obtained if the ground apple pulp is allowed to stand for several hours before it is pressed.

Other Factors to be Considered in Pressing

1. Washing. It is recommended that the apples be dipped for 5 minutes in a diluted acid wash followed by thorough rinsing in running water to remove the bulk of any spray residue and to decrease the amount of dirt and number of spoilage organisms on the fruit. Even washing the apples in water, while not as good as the acid wash, greatly improves the keeping qualities of the cider.

2. Iron is dissolved by prolonged contact with either the ground pulp or the cider, and under certain conditions is apt to cause blackening of the cider. Hence, all contact with iron should be reduced to a minimum.

3. Care of the cloths. Satisfactory press cloths may be obtained from a cider mill supply house. They should be thoroughly washed, boiled, and rinsed before using and, if possible, after each day's pressing. When used dry the cloths are apt to impart an undesirable flavor to the cider, so that it is advisable to soak the cloths overnight in clean cold water before a pressing is to be made with them.

4. Containers for the cider should be absolutely clean and free from any odors.

5. Unless cider is to be clarified with Pectinol (discussed later), it should be chilled as soon after pressing as possible. A temperature of 32° F. or below is the best storage temperature, but cider has been held for as long as a month at 40° F. without appreciable fermentation.

Action of Apple Juice and Cider on Metals

The acids in cider have a corrosive action on certain metals. The extent of this action on some of the more common metals, is given in the following list prepared by Charley (9):

Iron — Strong action with formation of green and brown tannates.
Tin — Slight action.
Copper — Badly attacked.
Aluminium — Slight action.
Zinc — Badly attacked.
Lead — Badly attacked.
Stainless steels — No action.

Proper selection of the metal equipment to be used in cider manufacture would not only be more economical over a period of years, but would also eliminate any danger of health hazards such as might occur if lead were exposed to the cider for any length of time. Off flavors and colors would also be developed if an excess of metals such as zinc, copper, and iron were dissolved in the cider.

A Small-Scale Apple-Juice Extractor

A machine for extracting apple juice on a small scale has been developed by Dr. Jenkins of Keene, New Hampshire. The purpose of the extractor is to enable soda-fountain operators and soft-drink dispensers to extract juice from fresh apples directly into a glass. The machine consists essentially of (1) a motor-driven disk covered with teeth which grinds the apple to a pulp, (2) a filter chamber containing a permanent non-clogging, metallic filter screen. The finely pulped apple is thrown by centrifugal force into the filter chamber and the juice is filtered through the metallic screen and led through a small pipe into the container. The solids automatically discharge through a separate pomace spout. (See Fig. 3.)

The juice extracted by this machine should not be classed as cider but rather as apple juice since it does not have the flavor or color of cider However, it is very palatable and should prove popular as a soda-fountain drink. Apple juice made by this extractor and sold in the same way as fresh orange juice should lead to an increased consumption of apples. Moreover, the fresh apple juice made by this machine was found to be as rich in vitamin C as the apple from which it was made, if consumed immediately, whereas pasteurized cider or cider held for a few days in storage was deficient in vitamin C.

Treatment of Containers

Cider can be spoiled very easily by storage for a few hours in a foul barrel. Several methods are available for the cleaning and sweetening of barrels.

Where live steam is available, thorough washing with hot water followed by treatment with live steam and a cold-water rinse is good procedure. Of course, use of hot water and steam removes paraffin from paraffin-lined barrels, and after such treatment it would be necessary to reline the container.

A moldy barrel should have the head removed and all the mold scraped off as well as the layer of wood underneath. Hot 5 percent soda ash (sodium carbonate) solution should then be scrubbed around the inside of the barrel after which it should be steamed or rinsed with several changes of hot water. Used barrels that appear to be sound should also be given the treatment with the hot soda ash solution.

Another method of sterilizing and deodorizing moldy or sour containers is to fill them with a solution of sodium hypochlorite (available at any drug store), or chloride of lime containing 500 parts per million of available chlorine, repeating the treatment until the container smells sweet. Thorough and repeated rinsing is necessary after this treatment.

Burning of sulphur in empty barrels before they are stored helps to keep them in good condition from one season to the next. Sulphur strips can be obtained from a cider makers' supply house.

Emphasis has been placed on the cleaning of barrels because they are so difficult to clean. Whenever possible it is better to keep cider in glass containers which can be kept clean and sterile with little trouble.

CLARIFICATION

The object of clarification of cider is to make the juice more easily filterable. Substances in the cider tend to form a slimy film on the filtering surface and slow down the speed of filtration. Hence, the clarification methods have as their object the breaking up of the viscous suspension so that the filter-clogging material is precipitated to the bottom of the container. The three best methods are given below.

Flash Heating Method

Carpenter and Walsh (8) suggest coagulating the suspended colloidal material by heating the cider to 180° F. for 20 seconds and cooling immediately. This method is satisfactory but requires flash pasteurization equipment.

Gelatin-Tannin Method

Numerous precipitating agents such as tannin and gelatin, white of egg, isinglass and blood, have been suggested as a means of clarifying cider. Of these the tannin-and-gelatin treatment is the most satisfactory for cider.

Addition of gelatin and tannin to the cider causes a fluffy precipitate to form which gradually settles to the bottom leaving the upper part of the liquid clear. Apparently the precipitate is caused by a combination of the pectin, gelatin and tannin. Apple cider ordinarily contains enough tannin to react with the gelatin, but to take care of the loss by precipitation additional tannin is added so that the taste will not be changed.

Since ciders differ in composition, it is necessary to test any given lot of cider to determine the amount of gelatin and tannin to add. For this purpose the following test solutions are made up. The description of the process is taken from Walsh (26). (See Figs. 4. and 5.)

> Solution 1. Dissolve ⅓ ounce of tannin in 5.95 fluid ounces of 95 per cent alcohol. Then add 23.8 fluid ounces of water and mix thoroughly.
>
> Solution 2. Dissolve ¾ ounce of gelatin in 23.8 fluid ounces of water and add 5.95 fluid ounces of 95 per cent alcohol. Heat a portion of the water and add the powdered gelatin slowly, stirring continuously. Then add the rest of the water and dissolve the gelatin by heating in a pan of hot water or double boiler and stirring. Add the alcohol and mix well.
>
> These solutions should be kept in separate stoppered glass containers and may be used as needed, the alcohol acting as a preservative in both cases. In some cases the gelatin solution will jell when cold, but it can be liquefied when needed by putting the container in hot water.
>
> Four white glass quart bottles should then be filled up to the neck with cider and numbered 1, 2, 3, and 4. Then add to each bottle the following amounts of solution 1 (tannin) and solution 2 (gelatin):

	Bottle No. 1	Bottle No. 2	Bottle No. 3	Bottle No. 4
Sol. 1 cubic centimeters....	10	10	10	10
Sol. 2 cubic centimeters....	5	10	15	20

(Note: A measuring cylinder or pipette, graduated in cubic centimeters may be purchased from a drug store or from a chemical supply or cider supply house. The test solutions could also be made up at a drug store.)

> Measure and add the amounts of solution shown to each bottle, adding the tannin solution first in all cases and shaking well after the addition of each solution. Let the bottles stand 10 minutes and the bottle which shows the most clear juice is the one to which the proper proportions of tannin and gelatin were added.

The quantity of gelatin and tannin to use for 100-gallon batches of cider is then found by referring to Table **. For smaller amounts of cider, proportionate amounts of tannin and gelatin are used. For example, if bottle No. 3 showed the greatest amount of clear juice at the end of the 10 minute period, 1.25 ounces of tannin and 4.2 ounces of gelatin should be added to 100 gallons of cider; for 50 gallons, one-half these amounts, or 0.63 ounce of tannin and 2.1 ounces of gelatin should be added to the cider.

TABLE ** AMOUNTS OF GELATIN AND TANNIN TO BE USED FOR 100 GALLONS OF CIDER BASED ON DIFFERENT TESTS

	Bottle No. 1	Bottle No. 2	Bottle No. 3	Bottle No. 4
Tannin, ounces	1.25	1.25	1.25	1.25
Gelatin, ounces	1.50	3.00	4.20	6.00

When the correct amounts of gelatin and tannin have been determined, the proper amount of tannin is dissolved in about 2 quarts of hot water (for a 100-gallon batch) and is then poured into the container of juice in a thin stream, stirring constantly. Ten minutes after the tannin has been put in the juice, the gelatin solution prepared by dissolving powdered gelatin in hot water as described for the test solution is added in like manner, with constant stirring. If the correct amounts of gelatin and tannin have been used, the juice starts to clear at once, and if left undisturbed, will be ready for filtration after standing 16 to 24 hours.

Disadvantages of the gelatin and tannin method are: (1) the cider is bleached by the treatment; (2) the precipitate is not as compact as with the Pectinol treatment; (3) the procedure is more complicated than the Pectinol method.

Advantages of the gelatin and tannin treatment are: (1) no heating is required during the treatment; (2) there is not as much loss of viscosity, unless the cider is subsequently filtered through a very fine filter. (3) The precipitation can be accomplished at a lower temperature than is possible with the Pectinol treatment.

Pectinol Method

The simplest method of clarifying cider is with Pectinol, an enzyme preparation made from certain molds with sugar as the vehicle. Pectinol breaks the soluble pectin in the cider down into simpler substances some of which are insoluble and settle out. As the insoluble material precipitates out it carries down other turbid colloidal matter which has lost the protective influence of the pectin.

The length of time required for the enzyme to clarify the cider depends on the temperature of the cider and the concentration of the enzyme. The following table taken from Hickok and Marshall (17), shows the quantities of Pectinol which are required to clarify cider under varying conditions of time and temperature. These figures are approximate since ciders vary in their composition.

OUNCES OF PECTINOL REQUIRED TO CLARIFY 100 GALLONS OF CIDER UNDER CERTAIN SPECIFIED CONDITIONS OF TIME AND TEMPERATURE

Temperature (Fahr.)	Time allowed for action of Pectinol 5 hours	15 hours	30 hours	48 hours
40°	....	30	15	10
60°	54	18	9	6
100°	14	5	....	....

The manufacturers recommend adding the Pectinol as soon after pressing as possible, using one pound for every 100 gallons of juice. The Pectinol should be sifted directly into the juice with gentle stirring and the juice permitted to stand overnight at room temperature (70° F.). There is no appreciable fermentation when the cider is held at room temperature for the time recommended, provided the juice is filtered and processed immediately after the clarification treatment.

Pectinol-treated cider must be heated at 140° F. for 10 minutes after clarification is complete to stop the enzyme action, as otherwise the pectin remaining in the juice is gradually broken down during storage and forms a deposit in the container. Pasteurization of the cider at any temperature above 140° F. will, of course, also stop the enzyme action.

Centrifuge Method

High speed centrifuges which are now on the market have been used to clarify cider, but we have never seen cider treated by this method and cannot say how satisfactory it is. Tests conducted on a small scale with cream separator and basket type centrifuges were unsatisfactory.

However, according to Marston (19) the supercentrifuge is used extensively in the manufacture of sparkling fermented cider in England. Charley (9, 10) reports that such ciders are more fruity and mellow than filtered ciders. Fermentation can be practically stopped by centrifuging. In the early stages, this treatment caused a small reduction in the fermentation rate, but when fermentation had gone far enough for the specific gravity to be down to about 1.025 it was stopped almost completely. The drawback to the use of this method is the slight haze permeating the cider. To get a brilliantly clear cider it is usually necessary to filter after centrifuging.

Effect of Clarification by Gelatin-Tannin and Pectinol on the Composition of Ciders

Samples of cider made from eight varieties of apples were clarified by the Pectinol and the gelatin-tannin methods and filtered. The filtered ciders as well as an untreated portion from each lot were then tested for ash, pectin, total acid, tannin and coloring matter, viscosity, pH, specific gravity, and degrees Brix. Results of this test are shown in Table 3.

The viscosity was much lower in the Pectinol-treated cider than in the gelatin-tannin and the untreated ciders. This is in agreement with the organoleptic test, since the gelatin-tannin treated cider has much more "body" than the Pectinol-clarified product.

While the pectin content is apparently decreased to the same extent by both methods of clarification, it must be remembered that the alcohol precipitate method was used in the determination. The alcohol would precipitate some of the decomposition products of the pectin which would show in the table as pectin. However, the decomposition products would be of such a nature that they would not affect viscosity as much as the pectin found in the untreated juice or in the gelatin-tannin treated product.

The pH of the various juices was affected but slightly by the clarification treatment.

The average of the total acidity values would indicate that the Pectinol treatment slightly increases and the gelatin-tannin treatment decreases the total acid content of cider. The increase in acidity in the Pectinol-treated

Table 3. — Composition of Ciders Clarified by the Gelatin-Tannin and the Pectinol Methods

VARIETY	Un-treated	Pectinol Treated	Gelatin-Tannin Treated	Un-treated	Pectinol Treated	Gelatin-Tannin Treated	Un-treated	Pectinol Treated	Gelatin-Tannin Treated	Un-treated	Pectinol Treated	Gelatin-Tannin Treated
	Specific Gravity			**Degrees Brix**			**Tannin**, percent			**Ash**, percent		
Baldwin	1.0409	1.0360	1.0470	11.8	11.0	11.5	.06	.04	.02	—	.21	.19
Ben Davis	1.0450	1.0450	1.0450	11.5	11.0	11.0	.06	.04	.02	—	.22	.16
King	1.0500	1.0500	1.0500	12.9	12.4	12.0	.07	.05	.03	—	.25	.17
McIntosh	1.0400	1.0397	1.0383	11.5	9.7	9.7	.08	.04	.03	—	.16	.14
Northern Spy	1.0452	1.0450	1.0450	12.0	11.0	11.9	.08	.05	.04	—	.18	.13
Rhode Island Greening	1.0450	1.0450	1.0450	12.0	12.0	11.9	.07	.07	.02	—	.15	.12
Roxbury Russet	1.0652	1.0600	1.0600	16.0	14.8	15.9	.06	.05	.04	—	.37	.15
Wealthy	1.0450	1.0409	1.0404	11.5	10.4	9.9	.05	.04	.05	—	.20	.18
Average	1.0470	1.0452	1.0463	12.4	11.5	11.7	.07	.05	.03	—	.22	16

	Viscosity			Pectin, percent			pH			Total Acidity, percent		
Baldwin	3.2	1.3	3.3	.10	.04	.05	3.5	3.5	3.6	.48	.44	.38
Ben Davis	3.8	1.4	3.4	.31	.19	.21	3.7	3.6	3.9	.43	.47	.33
King	7.3	1.7	3.1	.26	.19	.17	3.6	3 5	3.5	.53	.55	.44
McIntosh	4.6	1.3	1.5	.11	.03	.07	3.5	3.5	3.5	.48	.42	.38
Northern Spy	2.2	1.3	2.1	.09	.07	.06	3.4	3.4	3.4	.49	.58	.45
Rhode Island Greening	5.6	1.8	5.0	.30	.16	.15	3.5	3.4	3.4	.47	.58	.47
Roxbury Russet	4.7	1.5	4.5	.32	.17	.11	3.3	3.4	3.4	.67	.78	.57
Wealthy	4.2	1.4	2.9	.28	.12	.12	3.3	3.3	3.3	.61	.60	.57
Average	4.5	1.5	3.2	.22	.12	.12	3.5	3.5	3.5	52	.55	.45

juice is probably due to some of the decomposition products of pectin, such as pectic acid, which are formed by the action of Pectinol, but is so slight as to be of doubtful significance. Some of the slight decrease in the gelatin-tannin treated juice might be ascribed to the loss of tannin or tannic acid.

The clarified ciders had a lower specific gravity and Brix value than the untreated ciders, Pectinol causing more of a decrease in both instances than gelatin-tannin. Loss of pectin would be one factor responsible for the decrease in specific gravity and Brix value, but more important would be the small loss in sugar content through fermentation during the required settling period.

The average content of tannin and coloring matter was lowered more than a half by treatment with gelatin-tannin, but only a little less than a third by the Pectinol treatment. Since the gelatin-tannin treated cider is much lighter in color than the Pectinol treated, it is not surprising to find such a variation in the amount of tannin and coloring matter as determined chemically.

Ciders clarified with Pectinol had a higher ash content than did the gelatin-tannin treated juices.

FILTRATION

Much of the cider produced is not filtered, but experience shows that a clear cider is much preferred by the consumer. Small cider manufacturers often press the cider and store it in tanks overnight to settle. By siphoning the cider from the upper levels of the tanks, a fairly clear product can be obtained. Too long storage must be avoided or fermentation will occur and defeat the purpose of the tank clarification. In this state the semi-clarified juice may be filtered through a cloth filter or even through a filter press though a filter-aid is necessary if the latter is used. This process is best carried on in cool weather.

The muddy residue can be used for vinegar stock.

Muslin Tube Filter

A simple homemade filter has been developed at Michigan State College by Hickok and Marshall (17.) (See Fig. 6.) Their description of the muslin tube fruit juice filter and its operation follows:

> The set-up for performing the filtering operation consists of three principal parts:
>
> 1. A mixing and supply tank.
> 2. Elevation of the supply tank to provide a pressure head on filter unit.
> 3. The collecting or filtering unit.
>
> The collecting unit is the novel and most essential part of the outfit. It is a long, slender, cloth tube, closed at one end, with the other end connected to a rubber hose extending from the supply tank. This tube is laid in a horizontal position in a trough. When the mixture of cider and filter aid is fed into the closed tube, the pressure swells the tube to its full dimensions. The cider is forced out rather uniformly over the entire surface of the tube and the filter aid forms a cake of uniform thickness on the inside. The trough is given a slight slope so that the clear juice runs out of one end into a receptacle.
>
> The cloth tube is made of unbleached muslin, sewed to give a diameter of approximately three inches. A tube of a larger diameter will not support the filter cake satisfactorily and subsequent cracking and breaking of the cake may cause cloudiness in the filtered cider. A tube one yard long is most convenient. It cleans easily, coats evenly in a short time, and is the usual cloth width sold. It is recommended that both ends of the tube be left open to facilitate cleaning. In use, the dead end should be folded back, carefully gathered and tied, preferably with a single miller's knot.

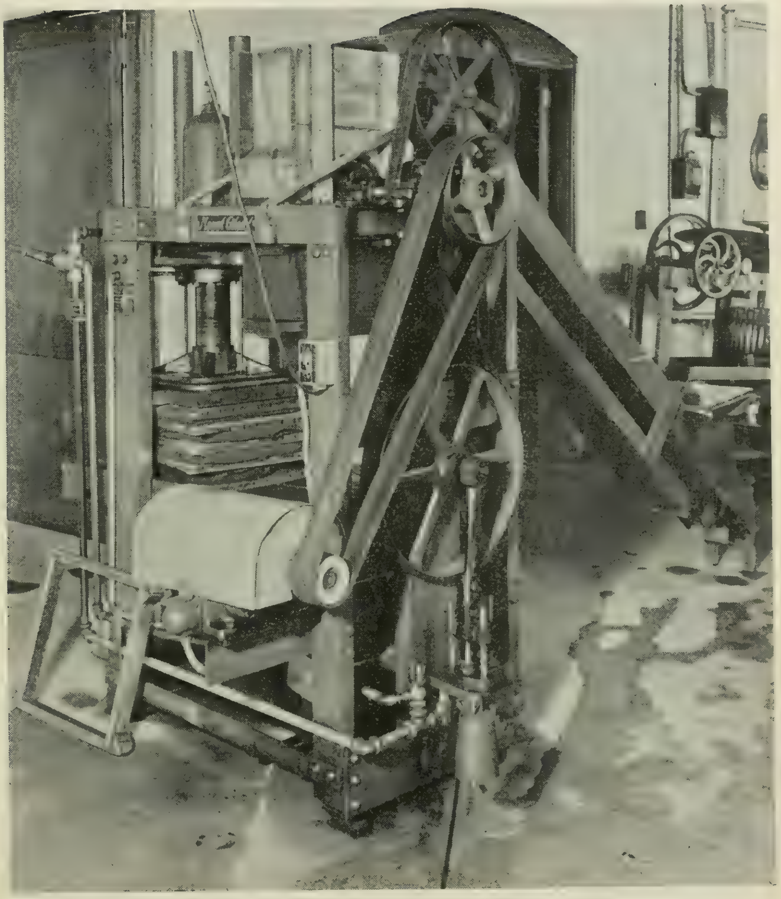


Figure 2. Hydraulic Press in the Food Manufacturing Laboratory
Small size with a capacity of 2½ bushels to a pressing.

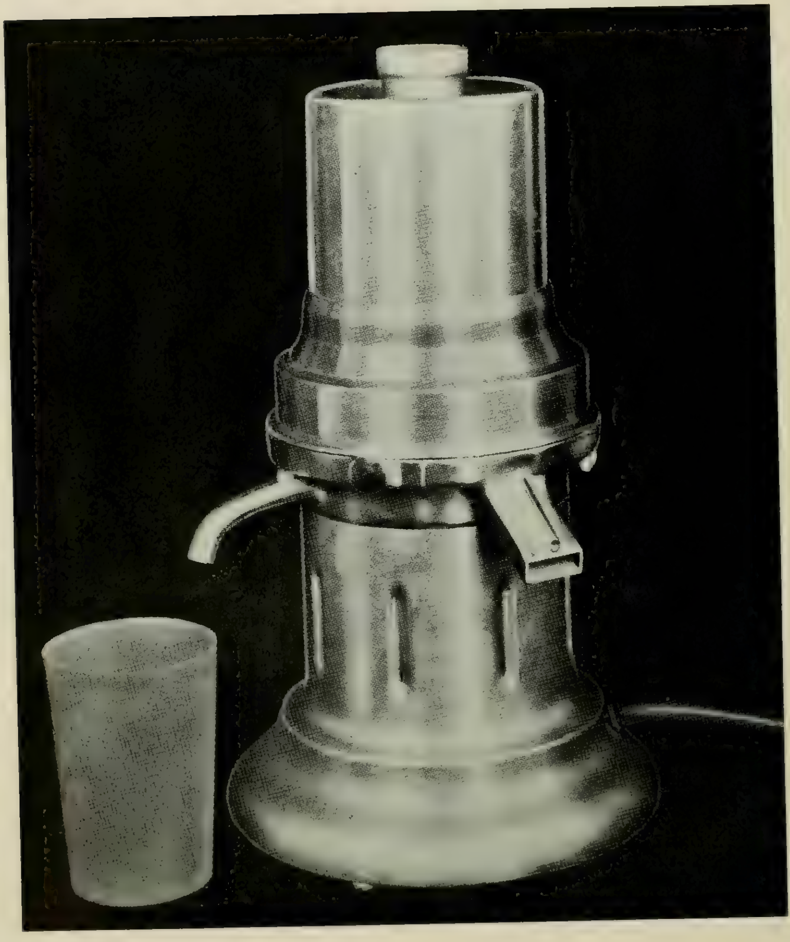


Figure 3. Vegetable and Fruit (non citrous) Juice Extractor.
Courtesy of Brooks L. Jarrett & Co., Pittsburgh, Pa.

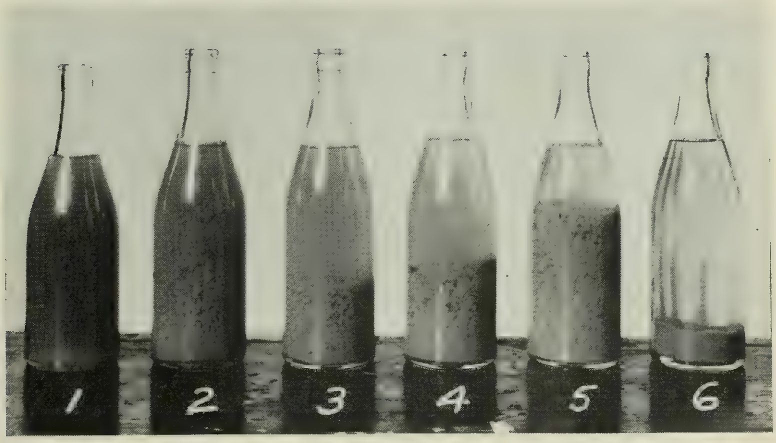


Figure 4. Gelatin-Tannin Treated Cider.

Bottle No. 1 contains untreated cider, No. 6 gelatin-tannin treated cider which has settled for 24 hours. Bottles No. 2 through 5 contain cider treated with gelatin-tannin test solutions in the following amounts per quart: No. 2, 5 cc. gelatin solution and 10 cc. tannin solution; No. 3, 10cc. gelatin solution and 10 cc. tannin solution; No. 4, 15 cc. gelatin solution and 10 cc. tannin solution; No. 5, 20 cc. gelatin solution and 10 cc. tannin solution. Note that the best break and precipitation is in bottles No. 3 and 4, and these bottles therefore would indicate the amounts of gelation and tannin to add to the main batch.

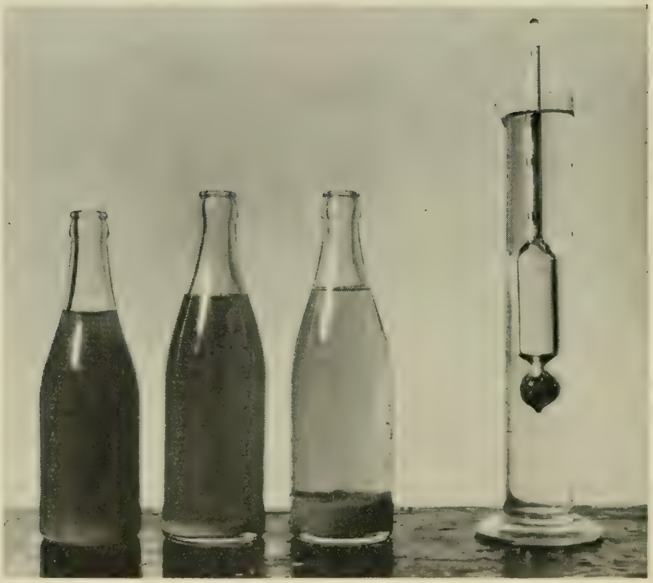


Figure 5. Comparison of Pectinol Treated and Gelatin-Tannin Treated Cider.

On the left is untreated cider; in the middle, Pectinol treated cider; and on the right, gelatin-tannin treated cider. Note how much more compact is the sediment in the Pectinol treated cider. The Brix hydrometer in the cylinder containing gelatin-tannin treated cider shows how clear the treatment renders the cider.

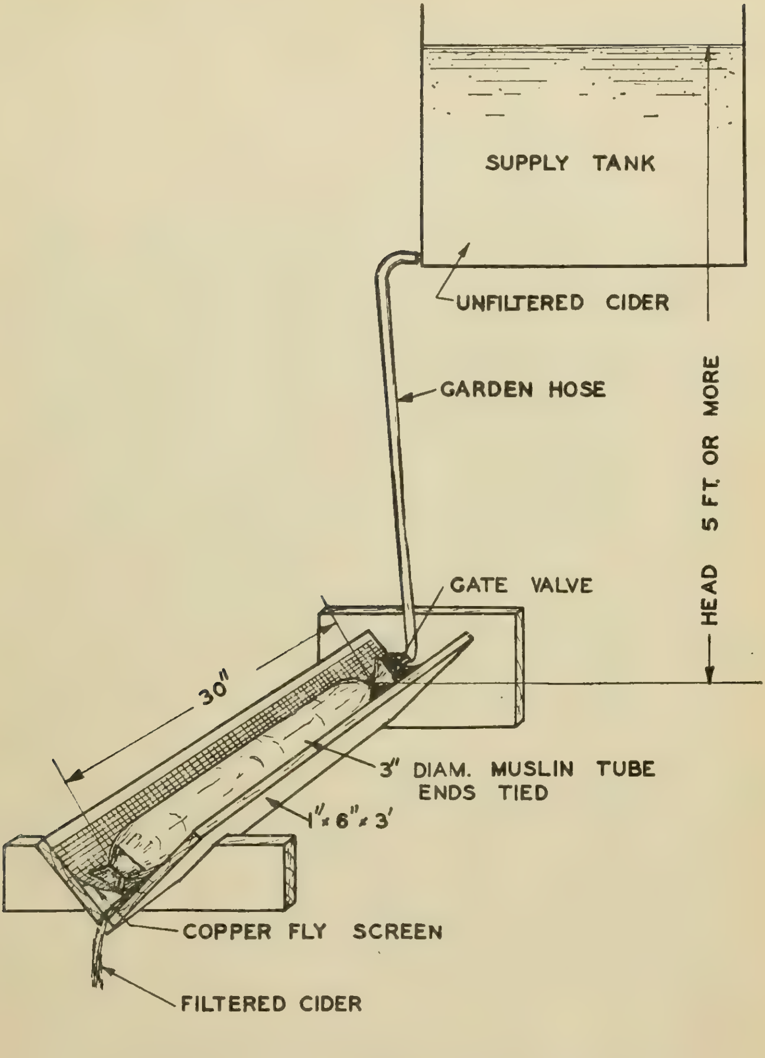

SUPPLY TANK
UNFILTERED CIDER
GARDEN HOSE
HEAD 5 FT. OR MORE
GATE VALVE
30"
3" DIAM. MUSLIN TUBE ENDS TIED
1"x 6"x 3'
COPPER FLY SCREEN
FILTERED CIDER

Figure 6. The Essential Elements of the Homemade Filter.

The tube should be supported in the trough by a copper screen. This allows free flow from the trough and makes the entire area of the tube effective in filtering. The copper screen is preferable to iron wire screen because it is less affected by fruit juices.

It is necessary to have a small pressure head on the filter. This can be satisfactorily secured by elevating the supply tank. The greater the elevation the more rapid the flow will be from the filter. The net head should not exceed 15 feet (with muslin tube) and eight feet results in very satisfactory operation. Less head may be used where small quantities are to be filtered, but will necessitate more frequent cleaning of the collector. Tests with cider subjected to enzyme clarification gave the following rates of filtration:

Net Head (Ft.)	Gallons Per Minute*
4	.65
6	1.05
8	1.43
10	1.80
12	2.50
14	3.34

*These were for short runs of about five gallons and rate would be lower for longer runs with thicker filter cakes.

The necessary head may be obtained in different ways: 1. The supply tank may be put on the floor of the upper story of a building and the filter below; 2. a platform may be constructed to support the supply tank at the desired height; 3. or the tank may be raised and lowered by a block and tackle or chain fall. Where a large amount of filtering is to be done, it may be more economical to use a pump† in connection with a storage tank. A pump may be directly connected to the filter, in which case it should be provided with a pressure control. For farm purposes, the cider can be carried or hand-pumped to the height of the supply tank.

The supply and mixing tank should be of wood. A barrel, with the head removed for filling and mixing, may be used where small quantities of cider are handled. Delivery to the filter should be through a rubber garden hose, preferably five-eights inches in diameter. The tank may be bored and fitted with a brass spigot, or the cider may be siphoned from the barrel. It is convenient to have a cut-off in the delivery hose. A convenient arrangement is a ½-inch gate valve at the lower end, fitted with two nipples. One ⅜-inch nipple with bushing will fit into the inside of the hose and the filter tube can be attached to the other. This arrangement is convenient for shutting off the flow to clean the unit and for starting the siphon. The muslin tube should be wrapped tightly around the nipple and tied with a miller's knot.

---

†Where a pump is used, it should be of bronze and with a minimum of metal in contact with the cider.

The muslin tube filter uses a "filter aid", which is absolutely essential to its successful operation. The "filter aid" used by this laboratory is known as Hyflo Supercel and is manufactured by Johns-Manville Company, the nearest local office being in Boston, Massachusetts. This product is a diatomaceous earth which has been heated to a high temperature, a process known as calcining, to remove traces of organic matter which might cause off-flavors in the filtered product. It is good practice to test a filter aid to see that it does not impart an earthy flavor to the cider. This can be done by stirring a tablespoonful of the product in a glass of cider, waiting for it to settle, and tasting the cider.

As noted under the description of the muslin tube filter, the filter aid is carried down from the supply tank with the cider and forms a cake on the inside of the cloth tube where it acts as a filtering medium by collecting the sediment from the clarified cider. In general one pound of Hyflo Supercel is sufficient for 30 gallons of cider, although as much as one pound for 20 gallons, or as little as one pound for 40 gallons may be necessary, depending upon the condition and extent of clarification of the cider. The filter aid must be mixed thoroughly with the cider before the filter is started and must be stirred during the filtration as otherwise it will settle out.

About two gallons of cider must be run through and returned to the supply tank before any is collected for use, because it takes about that quantity of cider to build up the filter cake. According to the inventors of the muslin tube filter the tube must be cleaned after 20 to 40 gallons have run through where a pressure head of six to eight feet is used, but with more pressure head the filter may be run longer without cleaning. To clean the filter, the tube is untied and the filter aid and sediment shaken out or washed out under running water, after which the tube may be returned to the filter

Filter Presses and Plate Filters

For large installations filter presses are preferred for the production of clear ciders. A list of manufacturers of equipment is given in the appendix. In general, each manufacturer can best give directions for use of his particular type of press and can define its limitations.

Freshly pressed apple cider cannot be economically filtered in a filter press without the use of a filter aid such as asbestos or diatomaceous earth. The colloidal matter present clogs the filters and makes them useless. However, after treatment with a filter aid or with Pectinol or gelatin-tannin, the filter presses are very satisfactory and give a brilliantly clear product. Accessory equipment such as storage tanks, pumps, and sanitary metal tubing is required when filter presses are used.

The so-called germ-proof filters used for sterilizing cider can be utilized only after the cider has been already clarified and pre-filtered.

PERSERVATION OF CIDER

Preservation methods have as their object the elimination or control of undesirable microorganisms. In sweet cider, the esential organisms which must be controlled are yeasts and molds: yeasts, because they ferment the sugars in the cider to alcohol; molds, because they present an unattractive appearance in the cider and also slowly use up the sugar and impart off-flavors to the product. Molds require much more air to carry on their activities than do yeasts, but yeasts are killed more easily by heat treatment and grow less readily at low temperatures than do molds. These points are mentioned because they are important considerations in the preservation of cider.

Preservation methods may be put into four general groups:

1. Germ-proof filtration.
2. Freezing.
3. Pasteurization.
4. Treatment with preservatives

Germ-proof Filtration

In this method, cider after a pre-filtration treatment is run through a filter with openings so small that while the cider can pass through the filter, yeasts and molds are prevented from doing so. After going through the filter the cider is run into sterile bottles; capped with sterile caps, and stored for two weeks or so to be sure fermentation will not take place. It is then ready for distribution. The advantage of the germ-proof filter method is that no heat is required, thus preventing any "cooked" flavor in the cider.

Disadvantages of the germ-proof filter are: (1) Care is required to assure sterility in the bottled juice. (2) The equipment is too expensive for the small manufacturer. (3) Such fine filtration removes much of the color and "body" from the cider.

Freezing

If cider is frozen solid in closed containers and held at a temperature of 10° F. or lower, it may be held from one season to the next without any appreciable change in its flavor.

The container in which the cider is to be frozen, whether it be a barrel, glass, or cardboard container, should not be filled more than three-quarters to four-fifths full, since the cider expands during the freezing process. The container should be covered to prevent the juice from acquiring foreign flavors during freezing.

Freezing does not destroy the yeasts and molds so that after the cider is thawed out it is almost as perishable as freshly pressed cider.

Sufficient time should be allowed for the frozen cider to thaw out after it is removed from storage. If the containers are not too large, they can be set in water and shaken occasionally. Large containers require as long as 24 hours to thaw out.

Cider may be kept fresh for several weeks by simply storing at temperatures of 32° to 36° F. Fermentation ultimately sets in, however, and cold-storage temperatures cannot be relied on to preserve the cider indefinitely. Cider will keep much longer in cold storage if it is chilled immediately after pressing.

Pasteurization

This term is applied to any method of heat treatment in which the food product is heated to a temperature less than the boiling point of water (212° F.).

It must be understood that pasteurization treatment does not always sterilize the product treated. In non-acid products such as milk, the object of pasteurization is to destroy certain disease-producing microorganisms without necessarily eliminating spoilage organisms. In an acid product such as cider or wine, the treatment is employed to destroy or inactivate spoilage organisms such as yeasts and molds, since disease-producing microorganisms are not ordinarily found in acid products.

The temperature employed depends upon the length of time that the product is heated. Heating the product to a high temperature for a short time is called "flash" pasteurization; heating at a low temperature for a longer period, 20 or 30 minutes, is called the "holding" method of pasteurization.

Flash Pasteurization

There is special flash pasteurization equipment made for the dairy industry which can be used to process cider. However, a small coil pasteurizer made from aluminum tubing has been used successfully to flash pasteurize small lots of cider here. The cider is fed by gravity through one coil which is immersed in a tank of water heated to the desired temperature. The juice then flows through a second coil which is surrounded by cold water. A thermometer inserted through an opening in a bronze T-joint joining the two coils indicates the temperature of the cider after it passes through the heated coil. The flow of the cider should be regulated so that the cider is heated to 185° F. before it reaches the cooling coil. The latter should cool the juice down to 140° F. Bottles and caps should be treated to kill any yeasts or molds on them. Boiling the bottles and caps for a minute is a good method of eliminating the spoilage organisms. The bottles should be filled as full as possible when bottled from a flash pasteurizer.

Holding Method of Pasteurization

In this method the clean bottles are filled with cider heated to 130° to 140° F., leaving about one and a half inches to allow for further expansion during the heating process. The caps are then put on all but one bottle. The capped bottles are put on their sides in the pasteurizing tank and covered with water. The uncapped bottle should be kept standing upright with the top one or two inches above the level of the water A thermometer is inserted in this open bottle and heat is applied to the tank. When the thermometer in the open bottle registers 165° F., the temperature is held at this point for 20 minutes. The bottles should then be removed from the vat and slowly cooled.

The size of the pasteurizing tank depends on the amount of cider to be handled. The bottles should not rest on the bottom of the tank but should lie on a platform of wooden slats or screening about one-half inch from the bottom of the tank.

A deposit forms in the bottom of bottles of pasteurized, unclarified cider because of the precipitation of heat-coagulable substances. Unclarified cider also acquires a much more pronounced "cooked" flavor when it is pasteurized.

It is a good practice to aerate pasteurized cider by pouring it from one glass to another just before it is drunk.

Treatment with Preservatives

Sodium benzoate is the chemical compound most commonly used for the preservation of cider. Fellers (14) gives the following practical suggestions for the use of sodium benzoate in fruit juices.:

> 1. Use only sodium benzoate of high quality that is free from objectionable odor and taste. "U.S.P." grade is better than "Technical" grade. So little is used to preserve beverages, that it is poor economy to use cheap, objectionable preservatives which may ruin the beverage.
> 2. Do not use salicylic, formic or boric acids. All are prohibited by law in this country.
> 3. For strongly acid fruit juices which are made from sound stock and are reasonably free from turbidity or sediment, from 0.05 to .075 per cent by weight (3.5–5.5 oz. per bbl.) of sodium benzoate will effectively check alcoholic fermentation. For less sour juices as well as those made from questionable stock, or which are not freshly pressed, from .075 to 0.1 per cent (5.5–7.0 oz. per bbl.) is necessary. After fermentation has started, or in juices of exceptionally heavy body or of low acidity, even more may be necessary.
> 4. It is very important to add the benzoate to the freshly pressed juice. Yeasts proliferate very rapidly in cider and fruit juices, and delays of even a few hours may seriously impair the efficacy of the preservative.
> 5. Before filling, clean all receptacles such as bottles, carboys and barrels very thoroughly with steam, hot water, or a 0.02 per cent sodium hypochlorite solution. The latter will not injure the taste of the beverage.
> 6. A satisfactory way to add the preservative is as follows: Dissolve 1 lb. of sodium benzoate in sufficient water or fruit juice to make exactly 1 gallon. Solution is hastened by heat and stirring. One pint of this solution contains 2 oz. of sodium benzoate. Add as many pints as necessary. Do not add the benzoate in powder form to cider or grape juice through the bung. The preservative is not readily soluble in cold juices and merely settles to the bottom of the barrel. Before the benzoate goes into solution the juice may ferment.
> 7. Do not expect sodium benzoate to prevent spoilage in non-acid beverages or foods. It is suitable only for acid fruit juices and foods.
> 8. Benzoate gives the best results, and smaller quantities may be used, if the juice is kept in cool storage.
> 9. Clarified juices are more easily preserved by benzoate than cloudy juices with sediment.
> 10. Dirty and partially decayed raw stock produces a juice containing a large number of microorganisms and suspended matter. Such a juice

is unsuitable for preservation with sodium benzoate.

11. Benzoated cider or grape juice will not make good vinegar or wine. However, any alcohol which is present in the juice will change to acetic acid in spite of the preservative. It is therefore useless to attempt to preserve fermented beverages by the use of sodium benzoate.

12. Declare the presence of sodium benzoate and the amount added in per cent by weight, on each container offered for sale.

Experiments with sodium furacrylate and furoic acids showed them to be inferior to sodium benzoate for preserving cider.

Katadyn Treatment

In this method the preservative used is silver in very minute amounts. Equipment is very specialized and is obtainable on a rental basis only.

The general procedure is to pass cider through silver electrodes which are connected to a source of electric current. The cider makes an electrical contact between the electrodes and definite amounts of silver are deposited in the cider depending upon the strength of the current and the quantity of cider passing between the electrodes during any given period of time. Definite information regarding the operation of the Katadyn equipment is provided by the company furnishing the equipment.

Tests made here on a small scale show that the Katadyn process will successfully preserve cider, but it does impart a metallic taste to the product, which decreases during storage. Yeasts are more easily controlled by the method than are molds, so that the Katadyn treatment combined with bottling under a vacuum to inhibit mold growth, was found to be the most satisfactory procedure.

The use of this process in the treatment of cider is comparatively recent in this country, so that no definite statement can be made regarding its practicability for large-scale production.

Canning

Plain cans should be used for canning cider instead of the enameled because the latter perforate badly. The juice is merely filled into the cans, exhausted for 15 minutes at 160° F. or preferably vacuumized to remove air, sealed, and finally pasteurized for 15 minutes at 160° F. The product will keep for several months in a cool place, but should not be held over from one year to the next.

The main problem in the canning of cider is the elimination of oxygen from the juice. It is the combined action of the oxygen and acid in the cider which is believed to be responsible for the unusually corrosive action of cider on tin cans.

A procedure for the canning of cider recommended by Tucker, Marsh and Cruess (25) is as follows: Place the cider in a vacuum tank, preferably glass lined or of stainless steel, and apply a high vacuum of 28 to 29 inches about 20 minutes to remove dissolved and occluded oxygen. Then flash pasteurize the cider for 30 to 60 seconds at 185° F. and run it directly into cans, filling to within one-quarter inch of the top. Seal at once and cool immediately in cold water.

Instead of flash pasteurizing, an alternate procedure would be to fill the cider into cans after the vacuum treatment, leaving a good headspace. Then heat the filled cans in water at 150° F. for about 10 minutes, seal the cans and process at 150° F. for 30 minutes for small cans.

In general, it is more desirable to concentrate the cider by vacuum and preserve in class containers rather than to can the pure cider in tin cans. A somewhat inferior cider concentrate can also be prepared by open-kettle boiling.

Such a product can be preserved by canning either in glass jars, bottles, or tin cans.

CARBONATED CIDER

Carbonation of cider not only produces a sparkling drink much superior to plain cider, but also aids in the preservation of the product. Carbon dioxide gas is the substance responsible for the effervescence and "bite" of carbonated drinks. This gas also exerts an inhibitory action on mold growth so that the pasteurization temperature for carbonated cider may be reduced to 150° F.

There are three general methods of carbonating cider: (1) Use of ordinary soda-water carbonators. (2) Natural carbonation by yeasts. (3) Use of solid carbon-dioxide or "dry-ice."

The use of regular soda-water carbonators can best be explained by the manufacturer of the equipment. Important considerations in the carbonation of cider are:

Carbon-dioxide gas is more soluble in cold cider than in warm; hence during carbonation the temperature should be kept at 40° F. or below.

The amount of gas dissolved at a given temperature is directly proportional to the pressure of the gas.

It is generally agreed that naturally carbonated cider is better than the artificially carbonated product. Carbon dioxide is one of the gaseous products given off during the fermentation of sugar by yeasts. If the fermentation proceeds in a closed container, much of the gas is dissolved in the cider due to the pressure created. Such would be the general process of the natural carbonation of cider. It is by this process that the best champagnes are carbonated and it is also the procedure generally used for carbonating homemade root beer. In the manufacture of champagne, the yeasts which cause the carbonation are removed after they have settled out during storage. This is called disgorging. In homemade root beer as well as in some of the sparkling ciders sold in England, the yeast is left in the bottle, the consumer having become accustomed to the sediment.

Closed Cuvee Method

The closed Cuvee method was developed so that natural carbonation of a juice could be accomplished and the resulting sediment could be removed by filtration rather than by the long settling period and disgorging process. The method was originally used for champagne, but Davis (13) has successfully applied it to the manufacture of sparkling cider. The essential steps in the process are as follows:

1. The cider is partially clarified with a high-speed centrifuge and put into the glass-lined or stainless steel fermenting vat.

2. A pure yeast culture is introduced to start the fermentation and the cider is fermented at a temperature of 70° F. or above until the pressure in the fermenting vat reaches 75 lb. per square inch. This usually requires two to three days with a formation of as little as one-half of one percent of alcohol by volume.

3. As soon as the desired pressure is reached the cider is filtered as it flows from the fermenting vat to the cooling tank. Pressure is first equalized between the two tanks and the filtration is accomplished through gas-tight equipment so that there is very little loss of carbon dioxide.

4. In the cooling tank the cider is cooled to 30° F. so that there will be better absorption of the carbon dioxide gas. It is held in the cooling tank for 48 hours.

5. The cider is then run through a Seitz germ-proof filter into a counter pressure bottling machine where it is bottled in sterile bottles and capped.

By means of the closed Cuvee process either a sparkling sweet or a fermented cider can be produced, depending on the length of time the fermentation is allowed to proceed. The equipment used is expensive, but it is claimed that a very good product can be made by this method.

Dry Ice Method

For carbonation of small lots of cider, Walsh (26) suggests the use of "dry ice" or solid carbon dioxide. The clean bottles are filled with clarified cider cooled to 40° F. or lower. The dry ice is chipped off, accurately weighed, and immediately put into the bottle, which should be sealed as quickly as possible with the crown cap. The bottle is then wrapped loosely with a heavy cloth to prevent injury in case a defective bottle should burst, and shaken until the carbon dioxide is absorbed.

The following table, taken from Walsh, shows the volume of carbonation obtained in an 8-ounce container with different weights of dry ice. For pints and quart bottles proportionate amounts of dry ice and cider are used. A carbonation of about two volumes is recommended for cider.

AMOUNT OF DRY ICE REQUIRED FOR DIFFERENT VOLUMES OF CARBONATION

Weight of Dry Ice Grams*	Volume of Juice Fluid Ounces	Volume of Container Fluid Ounces	Volume of Carbonation
1.0	7	8	1.8
1.5	7	8	2.8
2.0	7	8	3.9

*A balance suitable for weighing in grams can be obtained from a scientific supply house such as Central Scientific Company, Cambridge, Massachusetts; Will Corporation, Rochester, New York; Eimer and Amend, New York, N. Y.; W. M. Welch Scientific Company, Chicago, Illinois.

CONCENTRATED CIDER PRODUCTS

Boiled Cider

The simplest and oldest method of concentrating cider is by boiling in an open kettle until the juice has been reduced to approximately one-fourth to one-fifth the original volume. The resulting product is known as boiled cider and is often used in mince meat, apple butter, and for cooking purposes. The color and flavor are distinctly inferior to the vacuum prepared product. After concentration, the cider is strained through a cloth, sedimented by standing for 24 hours, and the clear liquid drawn off into clean containers. Preservation is accomplished by processing the boiled cider in boiling water for 15 minutes.

Other Cider Concentrates

Several methods have been suggested for the manufacture of cider concentrates. Gore (16) concentrated the cider by slow freezing and separation of the ice crystals with a basket centrifuge. With two or three successive freezings and centrifugings, the juice was concentrated so that one gallon was the equivalent of five gallons of the original cider. This method produced a very good product but the process is more expensive than evaporation under a vacuum.

Concentration of cider under a vacuum of 27 to 29 inches is another method of preparing a concentrate which retains color satisfactorily. However, many of the volatile flavoring materials are lost where an ordinary vacuum pan is used. Poore (21) found that practically all of the characteristic volatile flavor came over in the first 9 percent of the distillate when the cider was concentrated in a vacuum pan under a vacuum of 28 to 28.8 inches and a temperature between 96.8° and 123.8° F. When the distillate was redistilled the flavor was found in the first fourth that was recovered and when this was returned to the cider concentrate it had a good flavor.

To prevent the loss of the volatile flavoring constituents the Pfaulder Company of Rochester, New York, have designed a fruit juice concentrator with an ester impregnating unit. Experiments carried out by Carpenter and Smith (7) showed that by this method a concentrate could be made which, when properly diluted, was difficult to distinguish from the original juice.

Cider Syrup

This product differs from other cider concentrates in that part of the acidity is neutralized. Novick (20) in this laboratory, has found the following procedure for the manufacture of cider syrup very satisfactory. Sweet or mildly acid varieties are most suitable for cider syrup manufacture.

1. Clarify the juice with Pectinol and filter.
2. Neutralize the clarified cider to a pH of 5.1 with calcium carbonate or potassium carbonate. The addition of excess alkali causes a dark color and poor flavor, and should be avoided. Normally if approximately three-fourths of the acidity is neutralized a good product will be obtained.
3. Concentrate in a vacuum pan to 68–72 degrees Brix with as high a vacuum as possible, preferably 27 inches. Open-kettle concentration may be used, but the resulting syrup is darker and somewhat inferior in flavor.
4. Filter through cheesecloth, bottle, and pasteurize at 160° F. for 20 minutes. Cool quickly.

Cider syrup may be used as a table syrup in place of maple or blended syrup. It has a characteristic flavor, which while not particularly apple-like, is still very palatable.

Cider Jelly

This product is made by concentrating cider to the jelling point. Since pectin is one of the essential constituents of a jelly, only unclarified cider should be used.

The fresh sweet cider is boiled to 7° to 8° F. above the boiling point of water or until the product flakes off a spoon in the characteristic jelly test. A concentration of seven volumes of cider down to one volume is enough to produce a good jelly. The finished jelly is strained through a single layer of good cheesecloth and poured into clean dry glasses. When the jelly has set, melted paraffin is poured over the surface and the covers are put on or the jelly is capped with an airtight cover. Vacuum sealing after the jelly sets eliminates air and aids greatly in preventing surface growth of molds. Long cooking will darken the color of the jelly and give it a caramel-like flavor, so concentration should be as rapid as possible.

A variation in the older method of cider jelly manufacture consists in adding pectin extract obtained from apple pomace to the fresh cider in sufficient quantity to produce a jelly. For best results the cider should be concentrated to at least one-half its original volume, then the sugar and pomace extract added, and the mixture boiled rapidly to a jelly test. Such a jelly is much less tough and acid than the old-fashioned apple cider jelly. Pectin extracts are easily prepared by boiling pressed pomace with about five times its weight of water for 15 mintes, and straining or filtering the extract. Such pectin extracts may be prepared during the apple season and preserved either by canning or by freezing. A certain degree of concentration, 3 or 4 to 1, is desirable before storing the pectin extract. Of course the pomace may also be dehydrated and stored in the dry state. For the latter, only pomace which has been extracted with water and re-pressed should be used.

Jellies made by the use of pomace extracts (pectin) and cider are somewhat different in character from ordinary heat-extracted apple jelly or from old-fashioned cider jelly. Mint jelly can also be easily made by using pomace extracts, green dye and either mint leaves or extract. Strictly speaking, mint jellies are really not pure apple jellies, although they can be prepared from whole green apples such as Greenings.

USES FOR APPLE POMACE

Approximately 40 percent of the weight of the cider apples remains as pomace after the cider has been pressed out. If left around the cider mill the pomace becomes a breeding ground for yeasts, molds, and vinegar flies. Hence it is very important that it be disposed of as soon as possible.

There is much useful material left in apple pomace. Most of the jelly-making constituent, pectin, still remains in the pomace after pressing. In fact, many of the commercial pectin preparations are made from dried apple pomace. So, if the amount of pomace produced during the season justifies the expense, a pomace drier may be installed. Dried pomace can be stored in a dry place and manufactured later into a pectin preparation or used as stock feed.

As noted in the section on cider jelly, pectin extract may be obtained from the wet pomace and used in the manufacture of jellies. Such jellies must not be labeled "pure apple jelly" unless cider is mixed with the pectin extract at the time of manufacture in amounts which would make the composition of the finished product the same as that of a pure apple jelly.

To make the pectin extract, water to the extent of five times the weight of pomace is mixed with the pomace, the mixture is boiled for 15 minutes, and the liquid drained off and filtered. This pectin extract can then be filled into jars or cans and sealed. Gallon jars may be heated for 20 minutes at 212° F. if filled above 180° F. and stored for future use.

To obtain a clear pectin preparation such as is sold commercially, it is necessary to treat the pectin extract with diastase, a starch-destroying enzyme, to remove the starchy materials and then filter it. Diastase preparations may be bought at most drug stores in the form of extract powder or tablets or they may be purchased in larger quantities directly from the manufacturer (See list of supplies in Appendix). Such preparations as Clarex, Protozyme PX, and malt diastase gave good results in this laboratory. Because of greater ease of filtration, the addition of diastase clarifiers to the unconcentrated extracts is suggested. However, if good filtration equipment is available, the concentrated extracts may be clarified and filtered. Approximately 0.1 percent by weight of diastase clarifier is used. It is best to soak the powder in a small amount of water for an hour to facilitate rapid enzyme action. Approximately 7 ounces per 50-gallon barrel or 0.14 ounce per gallon of pectin extract is used. Directions on commercial enzyme preparations should be followed closely. The optimum temperature is 120° F. and the reaction period should be 90 minutes. However, lower temperatures for a longer period of time may be used. For example, at room temperature the diastase preparation may be left in the cider all night and the filtration accomplished the next morning. General methods for the handling and non-enzymic clarification of pectinous fruit juices have been described by Bell and Wiegand (2).

Results obtained here show that clarified pomace (pectin) extracts retain their jellying power much better than unclarified extracts. Processing methods have been discussed. The canned extract is stored preferably at cold-storage temperatures until ready for use. The pectin extracts also keep well in the frozen condition.

Kertesz and Green (18) showed that stored pomace containing 20 percent or less of moisture, did not actively support the growth of mold. Even at lower moisture contents, however, a gradual loss in pectin quality occurred during storage. These losses were believed not to be of enzymic nature, but rather due to moisture itself.

Apple pomace may also be used as a stock feed. The wet pomace may be stored in a bin, silo, or in a pile, if proper precautions are taken to allow for the weight of the pomace. As mentioned previously, dried pomace may also be used for feeding dry, or soaked with about two and one half times its weight of water. Experiments have shown that apple pomace is approximately equal to good corn silage in feeding value for dairy cows. It is advisable to feed the pomace after milking and to remove the milk from the feeding barn, since otherwise odors from this feed may be absorbed by the milk.

In some states distillers are using apple pomace as a cheap source of alcohol.

LEGAL ASPECTS OF ALCOHOLIC CONTENT OF CIDER

In the Federal Alcohol Administration Act it is stated, "The term 'wine' means (1) wine as defined in section 610 and section 617 of the Revenue Act of 1918, (U.S.C., title 26, secs. 441 and 444) as now in force or hereafter amended and (2) other alcoholic beverages not so defined, but made in the manner of wine, including sparkling and carbonated wine, wine made from condensed grape must, wine made from other agricultural products than the juice of sound, ripe grapes, imitation wine, compounds sold as wine, vermouth, cider, perry and sake; in each instance only if containing not less than 7 per centum and not more than 24 per centum of alcohol by volume, and if for non-industrial use."

However, in the Massachusetts Amendments to the Liquor Control Act the sale of cider containing alcohol is limited as follows:

"This chapter (the Liquor Control Act) shall not apply to the manufacture or storage of alcoholic beverages by a person for his own private use or to sales of cider at wholesale by the original makers thereof, or to sales of cider by farmers, not to be drunk on the premises, in quantities not exceeding in the aggregate the product of apples raised by them in the season of, or next preceding, such sales, or to sales of cider in any quantity by such farmers not to be drunk on the premises if such cider does not contain more than three per cent of alcohol by weight at sixty degrees Fahrenheit; nor shall this chapter apply to sales of cider by the original makers thereof other than such makers and farmers selling not to be drunk on the premises as aforesaid, if the cider does not contain more than three per cent alcohol as aforesaid, not to be drunk on the premises as aforesaid."

The Federal Alcohol Administration Act therefore does not apply to the manufacture or sale of cider unless it contains more than 7 percent of alcohol by volume. Such cider would be easily recognized as "hard" since practically all the sugar of the cider would have to be used up to produce 7 percent of alcohol. Sweet cider would rarely, if ever, attain such an alcoholic content without the addition of sugar.

Apparently no limitations are made by the state on the alcoholic content of cider if sold at wholesale by the original manufacturers, or on cider made by farmers from apples raised by them "in the season of, or next preceding such sales", if the cider is not drunk on the premises. As mentioned in the preceding paragraph, the sugar content of the cider would limit the alcoholic content to 8 percent by weight at the very most. Generally speaking, the alcoholic content of a fully fermented cider is estimated at one-half the percentage of total soluble solids (mostly sugar) in the freshly pressed juice. For example, an apple juice containing 12 percent solids will give a cider containing approximately 6 percent alcohol. Cider manufactured by farmers in Massachusetts from apples other than those produced in their own orchards, or by other manufacturers, must not contain more than 3 percent alcohol by weight. Such cider must not be drunk on the premises.

These regulations do not interfere with the manufacture and sale of sweet cider, since with modern methods of preservation such as pasteurization, cold storage, or use of sodium benzoate, it is easy enough to prevent cider from attaining an alcoholic content of 3 percent. Even if it is desired to produce a sparkling sweet cider, the small amount of alcohol produced in the process of natural carbonation would be much less than the limit set by the State Alcoholic Beverages Control Commission, provided the proper procedure was followed.

SPRAY RESIDUE PROBLEM

Arsenic and lead spray residues often persist on apples after picking. Only a small part of these toxic substances is removed by ordinary fruit washing methods. Commercially, apples are often washed in solutions containing from 0.5 to 1.0 percent hydrochloric acid. This treatment is effective in residue removal. Where visible residue is present on the fruit an acid wash is desirable. Of course only a part of the arsenic and lead passes into the cider. Experimental tests for arsenic on several lots of cider and apple butter manufactured from representative Massachusetts-grown apples showed only traces of this element. However, the U. S. Food and Drug Administration has seized at least one consignment of boiled cider which contained excessive arsenic and lead. The apples were grown in the Pacific Northwest where the spray residue problem is more serious because of scanty rainfall.

In general, except possibly in the case of concentrated apple products, it is not believed that sufficient toxic residue will be present on Eastern-grown apples to constitute a health hazard.

NUTRITIVE VALUE OF CIDER

Apple cider should be sold on its merits as a pleasant, refreshing beverage, not primarily because of its nutritional properites. However, it is deemed advisable to include here such information as is available on the nutritive value of cider.

Smith and Fellers (24) have shown that there is a wide variation in the vitamin C content of 21 varieties of Massachusetts grown apples. Seasonal or other variations, except storage, caused little change in the vitamin C content in any one variety. There is no apparent correlation between the vitamin C content of an apple variety and the chromosome number of that variety.

The daily protective level for guinea pigs varied from 4 grams (84 units per ounce) for Baldwin to over 25 grams (13 units per ounce) for McIntosh. The varieties tested may be conveniently classified as to their vitamin C potency as follows:

Very good (4 to 6.5 grams) (84 to 50 units per ounce): Baldwin, Northern Spy, Ben Davis and Winesap.

Good (7 to 10 grams) (48 to 34 units per ounce): Esopus (Spitzenberg), Rome Beauty, Red Astrachan, King, Roxbury Russet, Rhode Island, and Stayman.

Fair (10.5 to 15 grams) (32 to 22 units per ounce): Arkansas, Gravenstein, Wealthy, Cortland, King David, and Golden Delicious.

Poor (16 to 25 grams) (21 to 13 units per ounce): Jonathan, Delicious, Tolman, and McIntosh.

Cider, immediately after pressing, has just slightly less vitamin C than the apple from which it was made. However, as was shown by Fellers, Cleveland and Clague (15), although cider 24 hours old retained an appreciable amount of vitamin C, benzoated and pasteurized cider over 48 hours old had practically no protective value against scurvy. Titration tests for ascorbic acid on a bottled apple juice preserved by Seitz germ-proof filtration showed that from 2 to 4 quarts of the cider would be required daily to protect a man from scurvy, using the apple juice as the sole source of vitamin C. These bottled ciders contained only 4 to 8 units of vitamin C per ounce.

Apples have been found to contain some vitamin B and 6 to 7 units of vitamin G per ounce, so that cider would also contain these vitamins.

As to other nutrients it might be well to compare cider with milk. Cider contains approximately 0.4 percent protein, about one-eighth as much as whole milk; 0.5 percent fat, about one-eighth as much as milk; 12 percent carbohydrate, over twice as much as milk. It would take about 5.5 ounces of cider or milk to provide 100 calories. The daily energy requirement for a man doing sedentary work is 2,242 calories.

Cider also contains certain essential minerals, but not in the quantity that they would be found in some other foods. According to Sherman (23) there are approximately the following percentages of the various minerals in cider: calcium .007, magnesium .008, potassium .011, phosphorus .012, chlorine .005, sulphur .006, iron .0003. The ash of the apple or its juice is mildly alkaline, the ash from 100 grams being equivalent to approximately 3.7 cubic centimeters of normal alkali.

Unpublished experiments at this laboratory show that the consumption by young men of as much as 800 to 1,000 grams daily of McIntosh apples has no effect whatever on the blood alkali reserve. The urinary acidity was likewise unaffected by the consumption of these large quantities of apples.

GENERAL DISCUSSION

Most of the sweet cider which is manufactured in this country is sold in the fall and early winter, either in the fresh, untreated condition or as benzoated cider. Since simple clarification methods have been developed there is an increasing amount of clarified, filtered cider sold in grocery stores and roadside stands. This clarified cider is not usually preserved but is handled in much the same way as the unclarified cider; that is, benzoated, so it can be held for a few days at room temperature.

If available, freezing storage is the best method of preservation for cider.

For the small manufacturer, the next best procedure is pasteurization, either flash pasteurization with a coil pasteurizer or the holding method.

Carbonation of cider is desirable because it decreases oxidation changes and makes pasteurization at a lower temperature feasible, besides improving the quality of the cider as a beverage. Where large-scale manufacture makes installation of specialized equipment possible, naturally carbonated sweet cider would seem to be the best product to manufacture.

Storage of the bottled, processed cider is almost as important as the preservation treatment. Pasteurization or a similar process does not protect the cider from changes such as are caused by light and high temperatures. The best storage for bottled cider is a cool, dark, storehouse.

If cider is to become more than just a seasonal drink, as much care must be given to its manufacture as would be accorded a good wine. Whether the consumer demand for cider would justify such extra care is problematical, but the large demand for cider in the autumn would indicate that there is a potential year-round market for a good cider beverage.

Improved methods of manufacture make it possible to produce good cider concentrates, but the equipment is too expensive for the small manufacturer. Concentrated cider products such as boiled cider, cider syrup, and cider jelly can be made with simple equipment, but the market for such products is limited.

Apple pomace can be used in the preparation of a pectin extract or for stock feed if fed in combination with foods containing certain essential nutrients. In some states the pomace is used by distillers as a cheap source of alcohol.

LITERATURE CITED

1. Association of Official Agricultural Chemists. Methods of Analysis. Ed. 3. Washington, D. C. 1930.
2. Bell, J. C., and Wiegand, E. H. Extraction and clarification of pectinous fruit juices. Ore. Agr. Expt. Sta. Circ. 63. 1925.
3. Caldwell, J. S. Chemical composition of apple juices as affected by climatic conditions. Jour. Agr. Research 36:289–365. 1928.
4. Caldwell, J. S. Mean summer or "optimum" temperatures in relation to chemical composition in the apple. Jour. Agr. Research 36:367–389. 1928.
5. Caldwell, J. S. Chemical composition of American-grown French cider apples and other apples of like character. Jour. Agr. Research 36: 391–406. 1928.
6. Caldwell, J. S. Chemical composition of the juices of some American apples. Jour. Agr. Research 36:407–417. 1928.
7. Carpenter, D. C., and Smith, E. C. Apple juice concentrate. Fruit Prod. Jour. 13:233. 1934.
8. Carpenter, D. C., and Walsh, W. F. The commercial processing of apple juice. N. Y. State Agr. Expt. Sta. Tech. Bul. 202. 1932.
9. Charley, V. L. S. The chemistry of cider. Chem. and Ind. 11:743. 1933.
10. Charley, V. L. S. Fermentation control of ciders by the centrifuge method. Univ. Bristol Agr. and Hort. Res. Sta. Ann. Rept. 1933: 141. 1933.
11. Chenoweth, W. W. Food preservation. 344 p. illus. John Wiley and Sons, Inc., New York, 1930.
12. Davis, M. B. Report on cider and apple by-products investigations. Canada Expt. Farm, Ottawa. (No date).

13. Davis, M. B. The manufacture of sweet and fermented cider by the closed Cuvee method. Fruit Prod. Jour. 12:294. 1933.

14. Fellers, C. R. Sodium benzoate and benzoic acid. Preservatives for cider and other fruit juices. Fruit Prod. Jour. 9:113–115. 1929.

15. Fellers, C. R., Cleveland, M. M., and Clague, J. A. Vitamin C content of Baldwin apples and apple products. Jour Agr. Research 46:1039–1045. 1933.

16. Gore, H. C. Extensive experiments on the concentration of fresh cider by refrigeration. Fruit Prod. Jour. 1:16. 1932.

17. Hickok, R. B., and Marshall, R. E. The muslin tube fruit juice filter. Mich. Agr. Expt. Sta. Quart. Bul. 15 (3): 191–197. 1933.

18. Kertesz, Z. I., and Green, E. L. Factors influencing the pectin content of stored apple pomace. N. Y. State Agr. Expt. Sta. Tech. Bul. 179. 1931.

19. Marston, W. L. Five ways to make better 3.2 cider. Food Ind. 5:358. 1933

20. Novick, J. Fruit syrups. Master's thesis. Mass. State College. 1936.

21. Poore, H. D. The production of apple juices, concentrates and syrups. Fruit Prod. Jour. 14: 170–173, 201–203. 1935.

22. Shaw, J. K. Climatic adaptations of apple varieties. Mass. Agr. Expt. Sta. Ann. Rept. 23 (1910) Pt. 1: 177–245. 1911.

23. Sherman, H. C. Chemistry of food and nutrition. Ed. 4. 614 p. illus. Macmillan, New York. 1932.

24. Smith, G. G., and Fellers, C. R. Vitamin C content of twenty-one Massachustts grown varieties of apples. Amer. Soc. Hort. Sci. Proc. 31: 89–95. 1934.

25. Tucker, D. A., Marsh, G. L., and Cruess, W. V. Experiments on the canning of apple juice. Fruit Prod. Jour. 15:7. 1935.

26. Walsh, W. F. Cider making on the farm. N. Y. State Agr. Expt. Sta. Circ. 149. 1934.

APPENDIX

Partial List of Dealers in Supplies

The following list is included so that cider makers may know where supplies may be purchased. No specific recommendation for any listed firm or product is intended. Equally satisfactory products may often be obtained from other dealers.

Barrels

So many cooperages are located throughout the state that no attempt will be made to list them. The addresses can be found in the telephone directory.

Mail order houses such as Sears Roebuck and Company and Montgomery Ward also sell barrels which are satisfactory for cider storage.

Benzoate of Soda

Heyden Chemical Corp., 50 Union Sq., New York, N. Y.
Hooker Electrochemical Co., 60 East 42nd St., New York, N. Y
Monsanto Chemical Co., St. Louis, Mo.
Seydel Chemical Co., Jersey City, N. J.

Cider Presses and Cider Makers' Supplies

A. B. Farquhar Co., Ltd., York, Pa.
Hydraulic Press Mfg. Co., Mt. Gilead, Ohio
Palmer Bros., Cos Cob, Conn.
Thomas-Albright, Goshen, Ind.

Chemical Supplies and Equipment

Balances, chemicals, hydrometers, thermometers:
  Central Scientific Co., 79 Amherst St., Cambridge, Mass.
  Eimer and Amend, Third Ave., 18th to 19th St., New York, N. Y.
  Fisher Scientific Co., 709–717 Forbes St., Pittsburgh, Pa.
  Arthur H. Thomas, W. Washington Square, Philadelphia, Pa.
  Will Corporation, Rochester, N. Y.
Balances, hydrometers, thermometers:
  Howe and French, Inc., 101 Broad St., Boston, Mass.
Hydrometers, thermometers:
  C. J. Tagliabue Mfg. Co., 525 Old South Building, Boston, Mass.
  Taylor Instrument Co., 141 Milk St., Boston, Mass.
Most wholesale drug and pharmaceutical dealers also carry stocks of chemicals and supplies.

Clarifying Agents and Filter Aids for Cider and Pomace Extracts

Pectinol:
  Hydraulic Press Mfg. Co., Mt. Gilead, Ohio
Protozyme PX:
  Jacques-Wolfe and Co., Passaic, N. J.
Filter-cel:
  Johns-Manville, 75 Federal St., Boston, Mass.
Clarex, malt diastase:
  Takamine Laboratory, Inc., Clifton, N. J.

Dry Ice

Dry Ice Corporation of America, 50 East 42d St., New York, N. Y.
Local ice cream manufacturers can usually supply small quantities of dry ice.

Filters

Alsop Engineering Corp., 39 West 60th St., New York, N. Y.
American Seitz Filter Corp., 31 Union Square, New York, N. Y.
Hydraulic Press Mfg. Co., Mt. Gilead, Ohio
The Independent Filter Press Co., Brooklyn, N. Y.
Karl Kiefer Co., Cincinnati, Ohio
Palmer Bros., Cos Cob, Conn.
Scientific Filter Co., 3 Franklin Square, New York, N. Y.
T. Shriver and Co., Harrison, N. J.
D. R. Sperry and Co., Batavia, Ill.

Vacuum Pans and Special Equipment for the Manufacture of Cider Concentrate and Closed Cuvee Process

Pfaudler Co., Rochester, N. Y.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
4,500-2-'36. No. 9739.

14b
E
337

POLYTECHNIC
AGRICULTURAL BRANCH LIBRARY
BLACKSBURG

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 337 **December, 1936**

VIRGINIA AGRICULTURAL EXPERIMENT STATION

Observations and Experiments with Neurolymphomatosis and the Leukotic Diseases

By Charles S. Gibbs

The transmission of neurolymphomatosis through the egg, and of the leukotic diseases by means of viruses has been known for some time. This investigation was undertaken to determine some of the methods of the transmission with a view toward making the control measures now in operation more effective.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

OBSERVATIONS AND EXPERIMENTS WITH NEUROLYMPHOMATOSIS AND THE LEUKOTIC DISEASES

By Charles S. Gibbs,[1] Research Professor of Veterinary Science.

Neurolymphomatosis gallinarum (Pappenheimer, Dunn and Cone, 1929) or avian paralysis is a widespread, transmissible disease of fowls characterized by infiltrations and tumor-like formations in the motor nerves and resulting in paralysis of muscles which control motion and other functions of the body. More or less related to avian paralysis is a group of diseases collectively known as leukosis.

Leukosis may be defined as a disease of the blood and blood-forming organs. It is marked by changes in the blood, liver, spleen, lymph nodes, and sometimes other organs and tissues. Four types of leukosis have been recognized in this study: erythroleukosis, myeloleukosis, lympholeukosis, and monoleukosis.

Patterson (1932, 1936) and Johnson (1934) consider avian paralysis and the various types of leukosis to be manifestations of the same agent or virus. Emmel (1935, 1936) claims that these diseases are indirectly due to infection with the typhoid–paratyphoid group of microorganisms, the bacteria producing hemocytoblastosis which ultimately leads to leukosis and neurolymphomatosis. Furth (1935), Gibbs (1934), and Fenstermacher (1936) present evidence to show that these diseases are etiologically different, erythroleukosis and myeloleukosis being due to filterable viruses in the blood of affected birds, and lympholeukosis and neurolymphomatosis being caused by proliferating cells closely related to lymphocytes. The responsible agent in monoleukosis is unknown, due to the rarity of the disease in the domestic fowl and the fact it has not been extensively studied.

ERYTHROLEUKOSIS

Erythroleukosis is that form of leukosis in which immature erythrocytes or hemoglobin-free cells appear in the blood stream. These immature erythrocytes have different names according to the stage they are in when they come from the bone marrow. The most common forms observed in the chicken are polychrome erythrocytes and erythroblasts. The erythroblast is a more primitive form than the polychrome erythrocyte, and is not always readily distinguished from the myeloblast which occurs in another form of leukosis. When these primitive cells are found in the blood stream in appreciable numbers, something is seriously wrong either in the hematopoietic organs or in the blood itself. Similar types of hemocytoblastosis have been observed in extreme parasitism, severe hemorrhage, toxemia, and bacteriemia. The evidence thus far indicates that the appearance of immature erythrocytes in the blood is but a symptom, and a satisfactory diagnosis of erythroleukosis can not very well be made unless a complete history of the case is available.

---

[1] The writer wishes to express appreciation to certain flock owners, to members of the Department of Poultry Husbandry (Dr. F. A. Hays, in particular) for counsel and for birds used in these experiments, and to Mr. O. S. Flint for assisting in the photographic work. Technical assistance was provided for this study by the use of Educational Research Administration Funds.

Erythroleukosis has been experimentally transmitted from affected to healthy birds by inoculation of whole erythroleukotic blood by Furth (1931), and by the author.

In experiments in this laboratory, each chicken received intravenously 0.001 cc. of whole erythroleukotic blood per gram of body weight, with results shown in Table 1.

Also erythroleukotic plasma freed of blood cells and platelets by centrifugalization at 25,000 R.P.M. and made bacteriologically sterile by filtration through 2 percent collodion membrane, transmitted the disease to susceptible chickens. The plasma was inoculated intravenously into 60 chickens, until each received 0.001 cc. of the ultrafiltrate per gram of body weight. This experiment is reported in Table 1.

TABLE 1. — RESULTS OF INOCULATING CHICKENS WITH ERYTHROLEUKOTIC BLOOD AND PLASMA

Number of Chickens	Age (Weeks)	Unaffected	Erythroleukotic		
			Total	Died	Recovered
		Inoculated with Whole Erythroleukotic Blood			
20	2	5	15	13	2
20	8	9	11	9	2
20	24	12	8	5	3
60		26	34	27	7
		Inoculated with Erythroleukotic Plasma			
20	2	8	12	8	4
20	8	13	7	4	3
20	24	15	5	1	4
60		36	24	13	11

The data in Table 1 show that the causative agent in erythroleukosis was filterable and passed through 2 percent collodion membranes in sufficient quantity to reproduce the disease in susceptible chickens. Furthermore, the results indicate that healthy chickens offered some resistance to the disease and this resistance apparently increased with age.

Since the chickens on these two experiments showed no symptoms or lesions of neurolymphomatosis and, according to the Diagnostic Service reports, erythroleukosis is not common in Massachusetts, the investigation was closed.

MYELOLEUKOSIS

Myeloleukosis is that form of leukosis in which immature leukocytes, known as myelocytes, appear in the blood stream. Like the erythrocyte, the leukocyte is formed in the bone marrow. Therefore, myeloleukosis presents the same symptoms as erythroleukosis, and a common method of differentiation is by examining stained blood smears and noting the predominating type of cell present.

The experimental data reported in Table 2 indicate that the causative agent in myeloleukosis is in the blood of affected chickens.

Also, this experiment shows a possible age resistance to the disease, since the older or 24-weeks-old chickens were more resistant to myeloleukosis than either the eight- or two-weeks-old birds. None of the 60 chickens on this experiment showed any symptoms or lesions of neurolymphomatosis, which demonstrates that the two diseases are etiologically separate.

In order to test the filterability of myeloleukosis for comparison with neurolymphomatosis and other forms of leukemia included in this study, the same procedure was followed as was used to determine a similar property of erythroleukosis. The results appear in Table 2.

TABLE 2. — RESULTS OF INOCULATING CHICKENS WITH MYELOLEUKOTIC BLOOD AND PLASMA

Number of Chickens	Age (Weeks)	Unaffected	Myeloleukotic Total	Myeloleukotic Died	Myeloleukotic Recovered
Inoculated with Whole Myeloleukotic Blood					
20	2	7	13	11	2
20	8	10	10	7	3
20	24	12	8	3	5
60		29	31	21	10
Inoculated with Myeloleukotic Plasma					
20	2	10	10	7	3
20	8	14	6	4	2
20	24	17	3	0	3
60		41	19	11	8

The results of the experiments recorded in Table 2 indicate that myeloleukosis was due to an ultrafiltrate, found in the blood stream separate from the corpuscles and platelets during the course of the disease.

The results of these experiments on erythroleukosis and myeloleukosis, while not extensive, are in agreement with similar findings reported by Furth (1931), and indicate that both diseases are due to a filterable agent in the blood stream. While mixed cases of these two types of leukosis have been found in Massachusetts flocks, the diseases reported in this bulletin were entirely separate. According to the records of the Diagnostic Service, myeloleukosis appears to be more common in Massachusetts than erythroleukosis, and largely for this reason an attempt was made to discover if red mites (*Dermanyssus gallinae*) were in any way responsible for the transmission of this disease from sick to healthy birds. It was thought that since the virus existed in the blood of affected birds this insect might be incriminated as a vector.

Experiments with Red Mites

Four chickens having advanced myeloleukosis were placed in a flock of 19 healthy pullets and one healthy rooster which had never been exposed to leukosis in any form. Red mites were abundant in this house. All of the chickens on this experiment were three months old and the disease was allowed to run a natural course for one year. The experiment was started May 24, 1934, and was closed on May 24, 1935. During this period the birds were blood-counted weekly in order to detect the earliest symptoms of myeloleukosis. The results are recorded in Table 3.

TABLE 3. — CHICKENS EXPOSED TO NATURAL INFECTION WITH MYELOLEUKOSIS IN A HOUSE INFESTED WITH RED MITES

Chickens	Sex	Days Unaffected	Days Myeloleukotic	Days Alive	Results
MG–52468	Pullet	0	4	4	Died
MG–52469	Pullet	0	7	7	Died
MG–52473	Pullet	0	12	12	Died
MG–52481	Pullet	0	13	13	Died
MG–52482	Cockerel	4	10	14	Died
MG–52486	Pullet	26	17	43	Died
MG–52488	Pullet	43	40	83	Died
MG–52485	Pullet	71	24	95	Died
MG–52501	Pullet	13	120	133	Died
MG–52497	Pullet	150	7	157	Recovered
MG–52499	Pullet	200	30	230	Died
13	Pullets	365	0	365	Lived
MG–52502	Cockerel	361	0	365	Lived

Pullets MG–52468, MG–52469, MG–52473 and MG–52481, already affected with the disease when placed in the pen, died on the 4th, 7th, 12th and 13th days of the experiment.

Cockerel MG–52482 contracted the disease first. He had been in the house only four days and died on the 14th day of the experiment. He was replaced by a half-brother, MG–52502, which lived through the remainder of the experiment in good health. Pullets MG–52486, MG–52488, MG–52485 and MG–52501 contracted the disease before freezing occurred in the hen house, and MG–52497 did not show any indications of myeloleukosis until after some freezing weather had taken place and the red mites were not active. No infection took place in this flock after December 27, 1934, although the virus was known to be present in at least one affected bird, MG–52499, up to January 9, 1935. In other words, five of the pullets and one of the cockerels contracted myeloleukosis during the first six months of the experiment, and only one MG–52499, contracted the disease during the last part of the experiment. Thirteen of the pullets remained unaffected during the entire period.

Experiments Without Red Mites

When the preceding experiment was completed, the house was carefully disinfected with 5 percent cresol solution and dried before any birds were placed in it. On October 24, 1935, the second experiment was started and continued to July 1, 1936. Data are given in Table 4.

TABLE 4. — CHICKENS EXPOSED TO NATURAL INFECTION WITH MYELOLEUKOSIS IN A HOUSE FREE OF RED MITES

Chickens	Sex	Days Unaffected	Days Myelo-luekotic	Days Alive	Result
MH–42974	Pullet	0	5	5	Died
MH–42975	Pullet	0	6	6	Died
MH–42976	Pullet	0	10	10	Died
MH–42977	Pullet	0	17	17	Died
MH–42980	Pullet	25	41	76	Died
MH–42978	Pullet	30	35	65	Died
MH–42971	Pullet	47	29	76	Died
15	Pullets	247	0	247	Lived
2	Cockerels	247	0	247	Lived
MH–42979	Pullet	Died April 14, 1935 of peritonitis.			

Pullets MH–42974, MH–42975, MH–42976 and MH–42977, previously inoculated with myeloleukosis, died on the 5th, 6th, 10th and 17th days, respectively.

Pullets MH–42980, MH–42978, MH–42971 came down with myeloleukosis in 25, 30 and 47 days after the experiment commenced, and died 41, 35 and 29 days later. One pullet, MH–42979, became an internal layer and died of peritonitis. The remaining 15 pullets and 2 cockerels lived 247 days, which was the duration of the experiment. This investigation may have been influenced by the weather, since it was not started until October 10. However, the weather was warm up into December, and this mild period corresponds with the duration of the myeloleukosis, since the last bird to come down with the disease did so on December 10, 1935.

It is interesting to note that myeloleukosis died out in both flocks soon after freezing occurred. In Flock 1, infested with red mites, seven birds contracted myeloleukosis, one recovered, and six died. In Flock 2, free of mites, three died of myeloleukosis. These experiments indicate that red mites are a vector in myeloleukosis, since twice as many birds died in Flock 1 as in Flock 2; but this is not the only way in which the disease is spread, or there would have been no deaths from this cause in Flock 2. That so many of the birds, 61.9 percent in Flock 1, and 71.42 percent in Flock 2, appeared to be resistant was a surprise; and that the number of days that the birds were myeloleukotic varied from 7 to 120, the average for 10 birds contracting the disease naturally in both experiments being 35.3 days, was unexpected. The eight control birds on both experiments averaged to live 9.25 days only. These chickens when inoculated probably received larger doses of the virus than the chickens affected naturally.

If these birds had not been kept under strict observation with blood counts being made every week, some of them could easily have passed as healthy, since they laid occasionally and appeared to be well. It is possible that myeloleukosis is spread by traffic in latent cases.

MONOLEUKOSIS

One outbreak of monoleukosis has been observed in Massachusetts. In this type of leukosis the blood contains a large number of cells with bean-shaped nuclei. Due to the pressure of other work this disease was studied from a diagnostic point of view only. No other cases have appeared in this laboratory, and it is not known that this disease has ever been reported in poultry before.

LYMPHOLEUKOSIS

Lympholeukosis is a form of leukosis in which the lymph system is involved. The pathological cell in lympholeukosis is the lymphoblast. These cells are formed in the lymphoid tissue of the bone marrow, liver, intestines, and cecae (Jordan, 1935; Gibbs and Johnson, 1936). In the fowl the lymphoblast readily migrates into the blood stream, because the vascular system is open. In the early stages it can not always be distinguished from the myeloblast. Whenever lymphoblasts or any other premature cells appear in the blood they are treated as foreign bodies, and an attempt is made by the liver and spleen to remove them. In some cases these organs simply become distended with free cells, while in others the lymphoblasts become invasive and replace the normal liver and spleen cells, forming a neoplasm known as lymphoblastoma. A common form of lymphoblastoma in the fowl is "big liver disease." The cells composing a lymphoblastoma acquire other characteristics in addition to invasiveness, which appear in the chromatin material of the nucleus and may be brought out by special staining methods. They are smaller and more vesicular than the lymphocytes of the blood, and this vesicularity appears to be associated with invasiveness. In eyrthroleukosis and myeloleukosis the liver and spleen may be distended with erythroblasts and myeloblasts. Sometimes these cells are malignant and invade the liver and spleen resulting in the formation of erythroblastomas and myeloblastomas, but more often they are found filling the vascular spaces and seldom infiltrate extravascular tissues. The type cells composing the myeloblastoma contain coarse chromatin in the nucleus with a tendency toward vesicular arrangement. But vesicularity is not the most prominent characteristic of the myeloblastoma cells due to the greater prominence of the eosinophilic granules in the cytoplasm.

Every attempt to transmit lympholeukosis from diseased to healthy birds by means of blood and ground liver failed. An examination of the ground liver smears on slides stained by trypan blue (Evans and Schulemann, 1914), showed that nearly all of the cells had been destroyed. This may explain some of our earlier failures to transmit this disease.

After considerable trial and error an improved method was found for the transmission of lympholeukosis. The study of field cases revealed large numbers of lymphoblasts in the portal blood (Figure 1), some of which were in mitosis while others presented a vesicular arrangement typical of lymphoblasts. Blood from five spontaneous cases, containing these cells, reproduced the disease in susceptible chickens. Both intravenous and intraperitoneal inoculations were tried, with results recorded in Table 5.

Table 5. — Results of Inoculating Chickens with Portal Blood Containing Lymphoblasts

Blood Donors	Number of Chickens Inoculated	Age (Weeks)	Route Injected	Lympho-leukotic
F–286	3	8	Intravenous	1
MC–98267	4	2	Intravenous	2
O–7586	3	3	Intraperitoneal	1
O–2254	3	6	Intravenous	3
O–2084	4	4	Intravenous	3
O–2084	4	4	Intraperitoneal	2
O–2084	4	4	Subcutaneous	0

All of the chickens which came down with lympholeukosis showed typical symptoms and at necropsy lesions comparable to those found in field cases. A common symptom was anemia and paleness of the face, comb, wattles, and mucous membranes. The breasts and legs were emaciated, but the abdomens remained large and full, and the birds ate fairly well. Necropsy revealed the abdominal weight in the livers. The bone marrow was devoid of fat, and hyperplasia was confined to the lymph spaces only. Tissues taken from the liver, spleen, and lymph nodes along the digestive tract showed hyperplastic infiltrations.

Table 5 shows that 25 chickens were inoculated with portal blood containing lymphoblasts and 12 contracted the disease. Since this experimental study is concerned primarily with neurolymphomatosis, it is pertinent to point out that infiltration of the nervous system was not observed in any of these cases or in any of the field cases submitted for this investigation.

Next, 20 chickens of various ages were inoculated intraneurally with fresh portal blood from birds dying of lympholeukosis and none of them showed more than a scar at the point of inoculation. The median nerve, which is visible through the skin in Rhode Island Red chickens, was selected in 10 cases and the sciatic nerve was chosen in the others. These chickens were held for six months and none of them showed any indication of disease. The nerves appeared to be refractory to the lymphoblastic cells in the inoculum, and the dose was apparently too small to induce generalized lympholeukosis.

In order to determine what part, if any, the plasma played in the transmission of this disease, the cells were removed from portal lympholeukotic blood by slow centrifugalization and passed through 2 percent collodion filters under two atmospheres of negative pressure. The ultrafiltrate was inoculated intravenously into 10 chickens two months old, so that each received 2 cc. of the plasma. None of these chickens came down with the disease in six months, while four out of five control chickens inoculated in the same manner with whole blood contracted lympholeukosis. At the end of six months the 10 experimental birds were inoculated intravenously with 3 cc. of whole lympholeukotic blood, and seven came down with the disease, while three were resistant.

This experiment indicates that the causative agent in lympholeukosis is associated with a particular type of lymphoblast which may be distinguished from the lymphoblasts normally occurring in the blood by appropriate staining to bring out the arrangement of the chromatin material of the nucleus. This type of cell may be found in the liver, spleen, and portal blood of diseased chickens. Also, lympholeukosis may be transmitted to healthy susceptible chickens by inoculating portal blood containing large numbers of these living cells directly into the blood or abdominal cavity. If a virus is involved in lympholeukosis these experiments failed to indicate its presence.

NEUROLYMPHOMATOSIS

In a previous bulletin, Gibbs (1934) showed that neurolymphomatosis could not be transmitted by inoculating crushed nerve tumors into susceptible fowls and chickens. These experiments have been repeated with some modifications. In the work reported in this bulletin, the cells were squeezed out of diseased nerves into sterile physiological saline solution and a portion of them stained with trypan blue just before inoculation. If the neurolymphomatous cells took up the stain they were rejected as not being viable, but if they resisted the stain they were immediately inoculated into the birds chosen for the experiments. Whether the cells were living or dead was not deemed important in previous work, as it was thought that the disease might be due to a virus. But since no evidence of a virus could be found, an attempt was made to implicate the neurolymphomatous cells as the causative agent in this disease.

TABLE 6. — CHICKENS DEVELOPING NEUROLYMPHOMATOSIS AFTER INOCULATION WITH TRYPAN-BLUE-RESISTANT NEUROLYMPHOMATOUS CELLS

Number of Chickens	Method and Site of Inoculation	Location of First Symptom of Paralysis	Average Number of Days after Inoculation First Symptom Appeared	Average Number of Days after Inoculation Necropsy Performed	Nerves and Plexuses Involved
15	Intraneurally, right sciatic nerve	Right leg	58	65	Right sciatic
9	Intraneurally, right wing nerve	Right wing	53	65	Right brachial
4	Intravenously	2 Right leg	50	60	Right sciatic
		1 Left leg	55	60	Left sciatic
		1 Weakness	51	60	Vagus
2	Intraperitoneally	General weakness	60	75	Coeliac

First, 100 healthy two-weeks-old chickens that had never been exposed to neurolymphomatosis were inoculated in the nervous system with trypan-blue-resistant cells. In 50 the sciatic nerve was selected as the site of inoculation, and the wing nerve was used in the remaining 50 chickens. Fifteen of the chickens inoculated in the sciatic nerve showed paralysis of the leg on the side inoculated, and nine of the chickens inoculated in the wing nerves developed typical symptoms and lesions of neurolymphomatosis. In every case the neurolymphomas were found distally to the site of inoculation. The greater number of successful inoculations in the sciatic nerves may be due to the fact that this nerve is larger than the wing nerve and retains larger doses of the pathological cells. Further details of this experiment are given in Table 6.

Next, a group of 15 chickens, one month of age, was inoculated intravenously with four doses of 0.5 cc. suspensions of trypan-blue-resistant neurolymphomatous cells at intervals of two days, and four of them came down with neurolymphomatosis in the periods shown in Table 6.

Also, 15 chickens from the same flock as the last were inoculated intraperitoneally with the same doses of the same suspension, and two developed paralysis of the coeliac plexus. The results of this inoculation are reported in Table 6, with the preceding tests, so that the results of the four routes of inoculation may be compared.

This work indicates that neurolymphomatosis may be transmitted to chickens by inoculation of trypan-blue-resistant cells intraneurally, intravenously, and intraperitoneally. The sciatic nerve was preferable to the wing nerve because it is larger and the suspension can be injected into it with a greater degree of certainty. The intravenous route appeared to be more certain of positive results than the intraperitoneal, but the suspension must be injected slowly and in small quantities in order to prevent the formation of an embolus which may cause the sudden death of the chicken. Regardless of whether the chickens were two or four weeks of age, they showed symptoms from seven to ten weeks after inoculation, which is about the age at which they begin to come down with the disease in field outbreaks.

The Transmission of Neurolymphomatosis Through the Egg

Previous to the beginning of this study the writer had observed cells histologically indistinguishable from the pathological cells in neurolymphomatosis in the venous and arterial blood, as well as infiltrations into tissues adjacent to neurolymphomas. Aside from nervous tissue, ovarian and testicular tissue appeared to be the most susceptible to such infiltrations from the coeliac plexus, although other tissues were observed to be affected at times. In some infiltrated ovaries the cells penetrated into the ovules (Figure 2), and in affected testicles they passed into the tubules (Figure 3) and appeared to be free in the seminal fluid along with the spermatozoa. An attempt to follow the passage of these cells into the egg at the time of fertilization by histological methods had to be abandoned, because of the lack of trained technical assistance for such work.

Finally the problem was approached in a different manner. In this experiment eggs secured from 20 hens and 6 roosters showing symptoms of neurolymphomatosis were hatched and the chickens kept under observation for evidence of paralysis. Before presenting the data it should be pointed out that some of the hens were not in good condition and production was low. Also fertility was inferior due to the fact that the roosters were not always able to breed. These roosters were used because they were the only ones available and because it was impossible to determine beforehand the course of the disease. These handicaps necessarily limit the scope of this experiment; nevertheless, the results indicate that neurolymphomatosis is transmitted through the egg, as suggested by Doyle (1928, 1929), and in the 1932 and 1933 flocks the hen appeared to be entirely responsible. The results of these observations are reported in Tables 7, 8, and 9.

Table 7. — The Transmission of Neurolymphomatosis through the Egg
1932 and 1933 Hens and Roosters

Hens	Roosters	Number of Eggs Laid	Chickens		
			Hatched	Normal	Paralyzed
L- 90	S-1248	10	4	4	0
*M- 355		3	1	0	1
*M- 553		4	2	1	1
*M-1389		6	2	0	2
M-2352	MF-89875	3	3	3	0
M-2570		8	4	4	0
M-1882		1	1	1	0
*H-1492	D-9252	16	13	10	3
H-1492	M-1247	4	2	2	0
*H-1492	D-10412	10	5	4	1
M- 986	M-1247	1	1	1	0
*M- 986	D-10412	4	2	1	1
M-1953	M-1247	2	1	1	0
M-1953	D-10412	15	11	11	0
*M- 68	D-10412	1	1	0	1
*M-4269		5	2	1	1
M-1806		25	15	15	0
*M-1790		7	3	2	1
*N- 49		17	9	7	2
N- 504		29	25	25	0
M- 279	M-936	27	20	20	0
M-3065		1	1	1	0
*M-2397		3	1	0	1
*M-1992		2	1	0	1
20	6	204	130	114	16

*Hens producing chickens which developed neurolymphomatosis.

Of the 130 chickens hatched in this experiment, 106 lived to be four months or more of age, 90 showed no symptoms or lesions of disease when necropsied at eight months of age, while 16 developed neurolymphomatosis as indicated in Table 9, and 24 died of causes other than the disease studied.

The lineal descent of the chickens on the maternal side is indicated in Table 9, since each was pedigreed with the number of the hen which laid the egg from which the chicken hatched, with F-1, F-2, etc., added. F-1 indicates the first chicken hatched, F–2 the second, etc. The descent on the paternal side may be ascertained by comparing Tables 7 and 9.

The 11 hens showing lesions of neurolymphomatosis in the ovaries and in one or more ovules laid 83 eggs from which 45 chickens were hatched. Of these, 29 remained normal and 16 developed neurolymphomatosis. As nearly as could be determined by histological study, the disease did not appear in any of the chickens hatched from eggs laid before the infiltrations had appeared in the ovaries of the hens. Nine of the hens, in which the disease did not reach the ovaries, laid 121 eggs from which 85 normal chicks were hatched, and no cases of neurolymphomatosis appeared during the eight months of the experiments.

TABLE 8. — THE 1932 AND 1933 HENS AND ROOSTERS

(Results of necropsies made at the end of the experiment or soon after hens became unable to lay)

Bird No.	Nerves, Plexuses, and Organs Involved
Hens:	
L–90	Right and left sciatic; right and left brachial
M–355	Coeliac and ovary
M–553	Coeliac, ovary, brachial, and sciatic
M–1389	Coeliac, ovary, and mesenteric
M–2352	Right and left sciatic
M–2570	Left brachial
M–1882	Right and left sciatic
H–1492	Coeliac, ovary, and mesenteric
M–986	Coeliac, ovary, right and left brachial
M–1953	Left sciatic
M–68	Coeliac and ovary
M–4269	Coeliac and ovary
M–1790	Coeliac, ovary, and right sciatic
M–1806	Right sciatic
N—49	Coeliac, ovary, lumbo-sacral, and right sciatic
N–504	Right brachial and vagi
M–279	Vagi
M–3065	Coeliac and vagi
M–3497	Coeliac, ovary, right brachial, and left sciatic
M–1992	Coeliac, ovary, and left vagus
Roosters:	
S–1248	Ciliary and right brachial
MF–89875	Right sciatic
D–9252	Right sciatic
M–1247	Left sciatic and coeliac
D–10412	Right brachial
M–936	Plantar

TABLE 9 — CHICKENS FROM THE 1932 AND 1933 HENS AND ROOSTERS, WHICH DEVELOPED NEUROLYMPHOMATOSIS

Chicken Number		Age (Days)	Sex	Nerves, Plexuses, and Organs Involved
M– 355 —	F– 3	15	Cockerel	Right sciatic
M– 553 —	F– 1	121	Pullet	Vagi
M–1389 —	F– 1	40	Pullet	Right and left sciatic
	F– 2	304	Pullet	Ciliary
H–1492 —	F– 1	240	Cockerel	Ciliary
	F– 3	19	Pullet	Right and left sciatic
	F–10	144	Pullet	Coeliac and mesenteric
	F–13	332	Cockerel	Right sciatic and femoral
M– 986 —	F– 1	270	Pullet	Coeliac and ovary
M– 68 —	F– 1	195	Pullet	Right and left brachial
M–4269 —	F– 1	323	Pullet	Right sciatic and left brachial
M–1790 —	F– 2	240	Cockerel	Left sciatic
M– 79 —	F– 5	240	Cockerel	Ciliary
	F– 7	93	Pullet	Vagi
M–2397 —	F– 1	285	Pullet	Right sciatic
M–1992 —	F– 1	200	Cockerel	Coeliac and testes

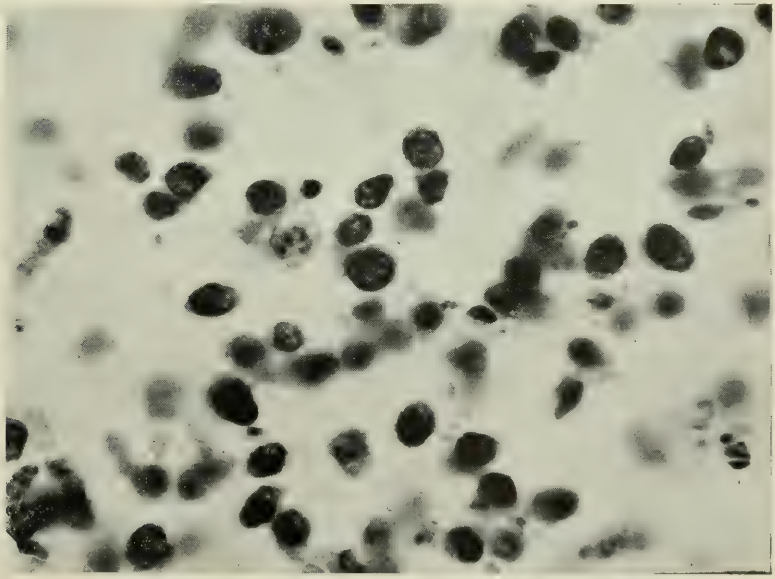


Figure 1. **Lymphoblasts in Hepatic-Portal Blood from a Case of Lympholeukosis (Magnified 950 diameters.)**

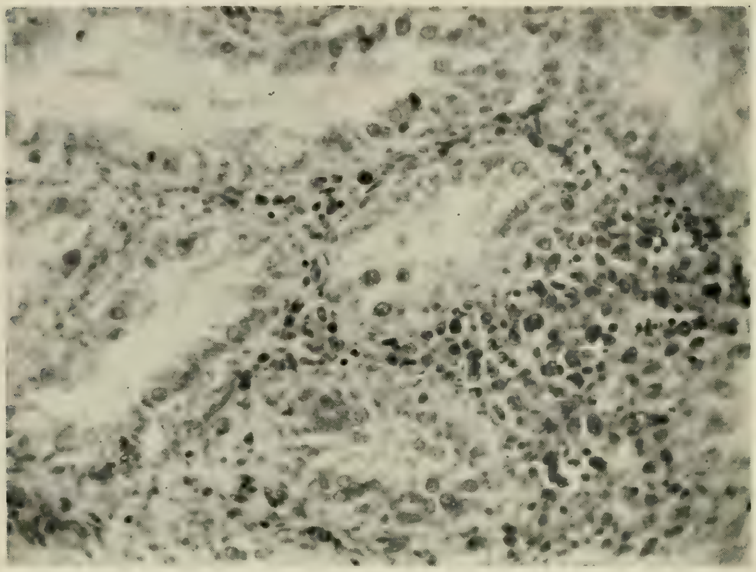


Figure 2. Neurolymphomatous Cells Infiltrating Ovule in Ovary of Hen Affected with Avian Paralysis (Magnified 950 diameters)

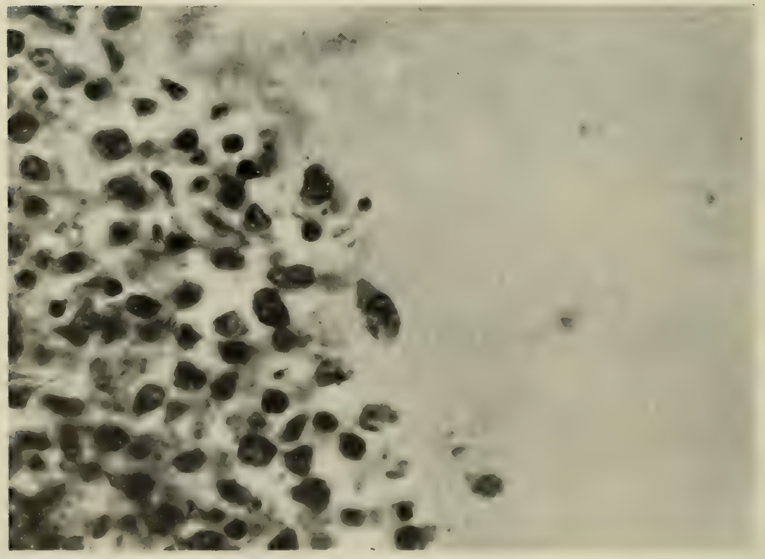


Figure 3. Neurolymphomatous Cells Passing into Tubes of the Testis of Rooster Affected with Avian Paralysis. (Magnified 450 diameters.)

TABLE 10.—THE TRANSMISSION OF NEUROLYMPHOMATOSIS THROUGH THE EGG
1934 AND 1935 HENS AND ROOSTERS

Hens	Roosters	Number of Eggs Laid	Chickens		
			Hatched	Normal	Paralyzed
*F– 286	D–10412	80	50	40	10
*F– 450		25	17	13	4
*F–1095		200	150	141	9
F– 498		10	9	9	0
*F– 455		2	1	0	1
*F– 458		5	5	4	1
F–1488		2	2	2	0
*F– 261	F–280	1	1	0	1
F–1398		110	64	64	0
*M–1389		210	130	127	3
*M– 986	F–393	240	118	108	10
M–4269		6	4	4	0
M–2397	F–492	2	1	1	0
E–1025		200	120	120	0
F–1063		155	93	93	0
*F–1064	MC–98345	10	6	5	1
*F–1064	F–387	4	3	1	2
F–24	MC–98345	11	5	5	0
*F–24	F–387	3	2	1	1
17	6	1276	781	738	43

*Hens producing chickens which developed neurolymphomatosis.

Of the 17 hens on this experiment, all showed infiltration of neurolymphomatous cells in the nervous tissue, but the ovaries were involved in only 8: F–286, F–450, F–1095, F–455, F–1488, F–261, M–986, and F–1064. These 8 hens laid 564 eggs from which were hatched 310 normal chickens and 38 which developed neurolymphomatosis. The 9 hens showing no lesions of neurolymphomatosis in the ovaries laid 712 eggs from which were hatched 428 normal chickens and 5 which developed neurolymphomatosis. Hens F–458 and F–24 were mated to roosters D–10412 and F–387 which showed lesions of neurolymphomatosis in the testes. Hen F–1389 was mated to rooster F–280, and three chickens from this mating developed neurolymphomatosis. The results from this mating do not support the findings secured with the 1932 and 1933 flock and the rest of the birds in this flock — that neurolymphomatosis is transmitted to chickens only after the ovaries or testes become infiltrated.

TABLE 11. — THE 1934 AND 1935 HENS AND ROOSTERS
RESULTS OF NECROPSIES

Bird No.	Nerves, Plexuses, and Organs Involved
Hens:	
F–286	Coeliac, ovary, proventriculus, and pericardium
F–450	Coeliac, ovary, and ventriculus
F–1095	Coeliac, ovary, ventriculus, and proventriculus
F–498	Left vagus
F–455	Coeliac, ovary, proventriculus, and left brachial
F–458	Coeliac and proventriculus
F–1488	Coeliac, ovary
F–261	Coeliac, ovary, crural, and right sciatic
F–1398	Nerves to the rectum
M–1389	Ciliary
M–986	Coeliac and ovary
M–4269	Right sciatic and left brachial
M–2397	Right sciatic
E–1025	Left ciliary
F–1063	Right ciliary and left sympathetic
F–1064	Coeliac, ovary, and right brachial
F–24	Coeliac, left sciatic, and vagus
Roosters:	
D–10412	Right brachial, coeliac, and testes
F–280	Coeliac, proventriculus, and left vagus
F–393	Coeliac and proventriculus
F–492	Left sciatic and peroneal
MC–98345	Coeliac and right testis
F–387	Coeliac and right testis

Infiltrations of neurolymphomatous cells were found in the testes of roosters D–10412, MC–98345, and F–387; while this organ was not involved in roosters F–280, F–393, and F–492.

The 43 chickens showing symptoms of neurolymphomatosis in the eight-month period during which they were kept under observation were necropsied, with results shown in Table 12.

TABLE 12. — CHICKENS FROM THE 1934 AND 1935 HENS AND ROOSTERS, WHICH DEVELOPED NEUROLYMPHOMATOSIS

Chicken No.		Age (Days)	Sex	Nerves, Plexuses, and Organs Involved
F-286	—C- 35	360	Pullet	Coeliac and ovary
	—C- 38	120	Pullet	Right sciatic
	—C- 39	130	Cockerel	Right sciatic
	—C- 40	175	Pullet	Right sciatic and vagus
	—C- 41	192	Pullet	Ciliary
	—C- 44	301	Cockerel	Coeliac and testes
	—C- 45	133	Pullet	Right and left sciatic
	—C- 47	202	Cockerel	Crural and coeliac
	—C- 49	104	Pullet	Vagi and right brachial
	—C- 50	186	Pullet	Coeliac, ventriculus, and proventriculus
F-450	—C- 13	60	Cockerel	Left sciatic
	—C- 15	322	Pullet	Coeliac, ovary, proventriculus
	—C- 16	209	Cockerel	Coeliac and testes
	—C- 17	128	Cockerel	Right sciatic and brachial
F-1095	—C-128	305	Pullet	Coeliac, ovary, and right sciatic
	—C-132	127	Pullet	Coeliac, ovary, and crural
	—C-139	248	Cockerel	Right and left sciatic
	—C-142	260	Cockerel	Crural, vagus, and proventriculus
	—C-144	215	Pullet	Coeliac, ovary, ventriculus, and proventriculus
	—C-145	199	Cockerel	Vagi and right laryngeal
	—C-147	308	Cockerel	Right and left ciliary
	—C-148	147	Pullet	Right ulna and median
	—C-150	222	Pullet	Coeliac and anterior mesenteric
F-455	—C- 1	239	Cockerel	Right and left sciatic
F-458	—C- 5	205	Cockerel	Right brachial and 14th and 15 cervical
F-261	—C- 1	182	Pullet	Right sciatic and crural
M-1389	—C-119	311	Cockerel	Coeliac, testes, and proventriculus
	—C-122	222	Pullet	Right sciatic
	—C-130	230	Cockerel	Right sciatic and left brachial

TABLE 12. — CHICKENS FROM THE 1934 AND 1935 HENS AND ROOSTERS, WHICH DEVELOPED NEUROLYMPHOMATOSIS

Chicken No.	Age (Days)	Sex	Nerves, Plexuses, and Organs Involved
M– 986—C–101	208	Pullet	Right and left sciatic
—C–102	201	Pullet	Right sciatic and crural
—C–103	299	Cockerel	Coeliac, testes, and ventriculus
—C–104	304	Pullet	Ciliary
—C–108	325	Cockerel	Ciliary
—C–109	124	Pullet	Right and left sciatic
—C–110	139	Cockerel	Right vagus and 1st, 2d, and 3d spinal
—C–113	239	Cockerel	Right and left vagus
—C–115	230	Cockerel	Right brachial and left ulna
—C–118	215	Pullet	Coeliac, ovary, and proventriculus
F–1064 —C– 7	289	Cockerel	Right sciatic
—C– 8	290	Pullet	Brachial
—C– 9	302	Pullet	Left sciatic
F–24 —C– 2	237	Pullet	Left sciatic and right vagus

A study of Table 12 shows that infiltration was present in the ovaries of six pullets, F–286—C–35, F–450—C–15, F–1095—C–128, F–1095—C–132, F–1095—C–144, and M–986—C–118, and the testes of four cockerels, F–286—C–44, F–450—C–16, M–1389—C–119, and M–986—C–103. It would have been interesting to know whether these birds would have become spreaders of the disease if they had lived to maturity, but it was impossible to continue the investigation further.

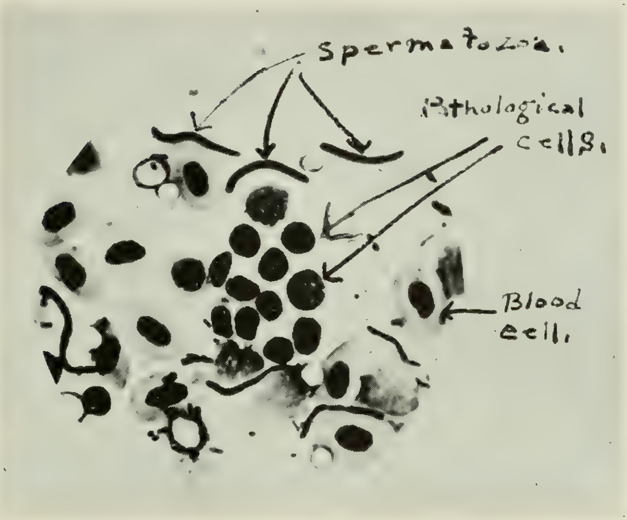

Spermatozoa.
Pathological cells.
Blood cell.

Figure 4. Blood and Neurolymphomatous Cells in Seminal Fluid of Rooster Affected with Avian Paralysis. (Magnified 950 diameters.)

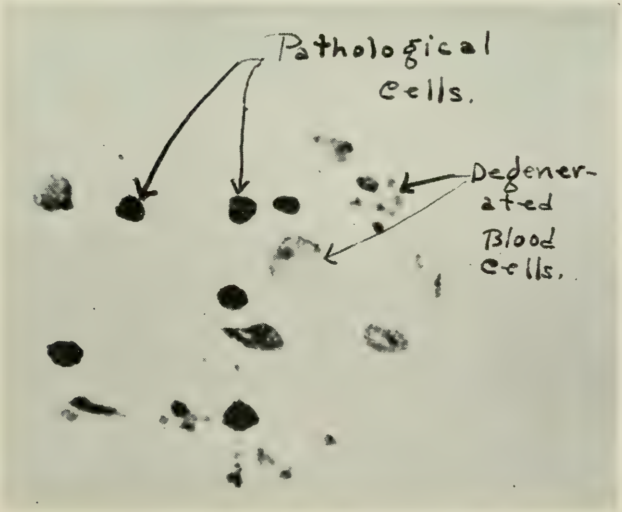

Pathological cells.
Degenerated Blood Cells.

Figure 5. Degenerated Blood and Neurolyphomatous Cells in Follicular Fluid of Hen Affected with Avian Paralysis. (Magnified 800 diameters.)

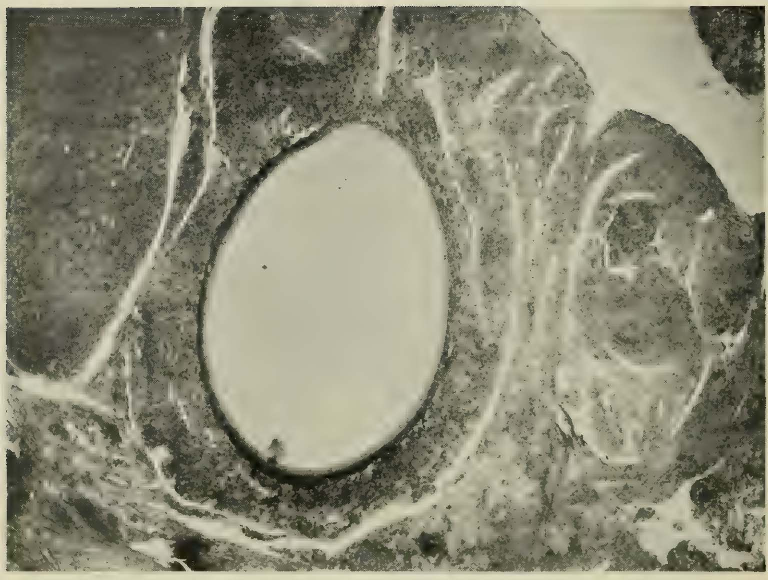


Figure 6. Ovule in Ovary of Hen F-1488, completely surrounded by Neurolymphomatous Tissue. (Magnified 150 diameters.)

Although the coeliac plexus and ovary of this hen were affected with neurolymphomatosis, the hen did not transmit the disease to chickens when mated to disease-free roosters.

The 1934 and 1935 Control Hens and Roosters

The house in which the 1934 and 1935 experiments were conducted had previously been divided into two compartments by means of chicken wire. The 20 hens and 6 roosters showing symptoms of neurolymphomatosis were placed in one pen, and 18 hens and 5 roosters showing no symptoms of disease were placed in the other as controls. The birds in both pens were cared for in as nearly the same manner as possible. No cases of neurolymphomatosis developed in either the control flock or their offspring. Table 13 shows the record of the control flock.

TABLE 13. — RESULTS WITH THE CONTROL FLOCK IN THE 1934 AND 1935 EXPERIMENT

Hens	Roosters	Number of Eggs Laid	Chickens Hatched	History of Hens
F–1096	F–500	4	3	Killed, poor layer
F–1382		50	42	Missing
F–1477		150	145	Killed, ate eggs
F–1478		5	5	Peritonitis
F–1495		7	4	Killed, runt
F– 466		2	1	Myeloleukosis
F–2411		3	1	Killed, poor layer
F–1391	F–500 MC–98380	235	202	Living
F–2402	F–500 MC–98380	232	176	Living
F– 428	F–1386	8	4	Myeloleukosis
F–1373		22	17	Myeloleukosis
F–1473	F–1386 MC–98380	240	171	Living
F–1493	F–1397	34	25	Peritonitis
F– 59	F–1397 MC–98380	202	142	Killed, ate eggs
MC–98422	MC–98380	135	108	Living
MC–98423		130	105	Living
MC–98426		80	67	Living
MC–98409		92	74	Living
18	4	1631	1292	

The data in Table 13 show that 18 hens and 4 roosters from families free of neurolymphomatosis produced 1631 eggs from which 1292 healthy chickens were hatched. This is an average production of 90.6 eggs per hen for the period under investigation. The hatchability for this flock for the same period was 79.21 percent. For comparison, the average figures for the 1932 and 1933 birds with neurolymphomatosis were 10.2 eggs per hen and 64.5 percent hatchability. The average production for the 1934 and 1935 birds with neurolymphomatosis was 75.05, and the hatchability 61.20 percent. Hence it is evident that the control flock, or the birds free from neurolymphomatosis, produced more eggs with a somewhat higher hatchability than the two flocks with neurolymphomatosis reported in this study. The loss from neurolymphomatosis in the 1932 and 1933 flocks was 12.30 percent, in the 1934 and 1935 flocks 5.50 percent, and in the control flocks none.

Neurolymphomatous Cells in the Seminal and Follicular Fluids of Roosters and Hens Affected with Neurolymphomatosis

The discovery by Burrows and Quinn (1935) of a method for obtaining spermatozoa from roosters and the application of the same to the study of the follicular fluid of hens was of considerable assistance in the investigations which follow. This technique would have been of assistance in determining the course of the infiltration into the ovaries and testes of the birds on the previous experiments had it been known.

In this work the semen and follicular fluids were collected on clean microscopic slides, air-dried, and the smears stained either with Leishmann's stain as advocated by Downham and Crompton (1934) or any other stain with which the investigator may be familiar. At first Unna's alkaline methylene blue and eosin was used and the preparation compared with histological sections of diseased nerves stained by the same method, until some experience had been obtained in identifying the cells in the stained smears by the vesicular arrangement of the nucleus (Gibbs and Johnson, 1936).

Before the method of Burrows and Quinn was known, the birds on the 1932 and 1933 experiment had either died or been killed for necropsy and histological study, so the semen and follicular fluids of these birds were not examined. Likewise the 1934 and 1935 project was about completed, since most of the original hens and roosters had either died or were incapable of breeding. However, roosters F–387, F–393, and F–492 and hens F–1064, F–24, M–986, M–4269, M–2397, E–1025, and F–1063 were living, and microscopical examination revealed structures indistinguishable from neurolymphomatous cells in the semen of rooster F–387, which were not evident in that of roosters F–393 and F–492. A check-up on the history of these birds, shown in Table 10, revealed some interesting but rather indefinite data which indicate that this rooster may have played a part in the transmission of neurolymphomatosis through the egg.

As indicated in the table, rooster F–387 was mated to hens F–1064 and F–24. From these matings seven eggs were secured and five healthy chickens hatched; however, three of the chickens, F–1064—C–8, F–1064—C–9, and F–24—C–2 came down with the disease when 290, 302, and 237 days old, respectively (Table 12). Thus rooster F–387 produced one normal and two paralytic chickens when mated to hen F–1064, and one normal and one paralytic chicken with F–24. At necropsy hen F–1064 showed lesions of neurolymphomatosis of the ovary, which was confirmed by histological examination. Neurolymphomatous cells had penetrated the coeliac plexus of hen F–24, but no evidence of infiltration could be found in the ovary. Neurolymphomatous cells were found infiltrating the coeliac plexus and the right testis of rooster F–387. The left testis was normal and contained living spermatozoa, although the bird showed no inclination to breed during the last two weeks of its existence. Since neurolymphomatous cells were found in the follicular fluid of hen F–1064 and infiltrations of the same cells were found in the ovary, rooster F–387 may not have been responsible for the transmission of the disease to his offspring, chickens F–1064—C–8 and F–1064—C–9. The follicular fluid of hen F–24, however, remained free of neurolymphomatous cells and no evidence of disease was found in the ovaries. It may be that the cells were transmitted in the seminal fluid from rooster F–387 to the egg from which chicken F–24—C–2 hatched. The details of such a transmission, if it occurred, have not been worked out.

Rooster F–393 was mated to hens M–986 and M–4269. M–986 (Table 10) laid 240 eggs from which 118 chickens hatched. Of these, 108 proved to be healthy, while 10 were affected with neurolymphomatosis. All of the diseased chickens appeared in the later hatches, or during the month when the bird went out of production and neurolymphomatous cells repeatedly appeared in the follicular fluid. After the bird had ceased laying, she was necropsied and the ovary was found to be completely infiltrated with the pathological cells of the disease. Hen M–4269 laid 6 eggs from which 4 healthy chickens hatched and remained free of neurolymphomatosis. This hen had a more acute attack of the disease than M–986, but the symptoms and lesions were confined entirely to the right sciatic nerve and the left brachial plexus.

Rooster F–492 was mated to hens M–2397, E–1025, and F–1063. From these matings 357 eggs and 214 chickens were secured, all free of neurolymphomatosis. Gross and histological examinations revealed no evidence of the disease in either the testes of the rooster or the ovaries of the hens, nor were the disease cells found in the seminal or follicular fluids.

These findings indicate that neurolymphomatosis is usually not transmitted through the egg unless the ovary of the hen or the testes of the rooster are infiltrated. In the case of the infected rooster, the disease may not be transmitted unless the cells are present in the semen; but in the hen they may pass directly from the ovary into the developing ovule.

Since no more of the original hens and roosters on the neurolymphomatosis project were available for further investigation, in order to clear up these points a new experiment had to be set up, using offspring from the original birds and pullets and cockerels donated by interested poultrymen. In selecting birds for this investigation, 40 hens and 21 roosters showing symptoms of the disease were examined, and 7 hens and 10 roosters were found to have neurolymphomatous cells in the follicular and seminal fluids. The following matings were made with the seven hens and seven of the roosters.

Two chickens which developed neurolymphomatosis resulted from each mating in which pathological cells were found in the follicular and seminal fluids. The hatchability was 61.4 percent and the percentage of neurolymphomatosis occurring in the chickens hatched was 11.54.

TABLE 14.—THE TRANSMISSION OF NEUROLYMPHOMATOSIS THROUGH THE EGG

Mating 1. Hens and roosters showing the pathological cells in their follicular and seminal fluids.

Hen No.	Rooster No.	Number of Eggs Laid	Chickens Hatched	Chickens Normal	Chickens Paralyzed
F- 286—C- 35	F-286—C-44	25	16	14	2
F-1095—C-128	M-1389—C-119	32	19	17	2

Necropsy Report on Birds in Mating 1

Bird No.	Nerves, Plexuses, and Organs Involved
Hens:	
F- 286—C- 35	Coeliac and ovary
F-1095—C-128	Coeliac, ovary, and right sciatic
Roosters:	
F- 286—C- 44	Coeliac, testes, and right sciatic
M-1389—C-119	Coeliac, testes, and proventriculus

Chickens from Mating 1, which developed Neurolymphomatosis

Chicken No.	Age (Days)	Sex	Nerves Involved
F- 286—C- 35—C-15	250	Pullet	Right and left sciatic
F- 286—C- 35—C-16	120	Pullet	Right and left sciatic
F-1095—C-128—C-17	147	Cockerel	Right sciatic
F-1095—C-128—C-19	199	Pullet	Right sciatic and vagi

TABLE 14. — THE TRANSMISSION OF NEUROLYMPHOMATOSIS THROUGH THE EGG

Mating 2. Hens showing the pathological cells in their follicular fluids, mated to roosters with seminal fluids free of the cells.

Hen No.	Rooster No.	Number of Eggs Laid	Chickens Hatched	Chickens Normal	Chickens Paralyzed
VQ-1803	VQ-1847	18	15	15	0
VQ-1908	VQ-1870	5	1	1	0
VQ-1908	VQ-2241	20	14	12	2

Rooster VQ-1870 developed acute symptoms of neurolymphomatosis two weeks after the experiment started and went down with leg weakness. He was replaced by VQ-2241, and the investigation continued.

Necropsy Report on Birds in Mating 2

Bird No.	Nerves, Plexuses, and Organs Involved
Hens:	
VQ–1803	Coeliac, proventriculus, and ventriculus
VQ–1908	Coeliac, right and left brachial
Roosters:	
VQ–1847	Ciliary
VQ–1870	Right and left sciatic
VQ–2241	Ciliary

Chickens from Mating 2, which developed Neurolymphomatosis

Chicken No.	Age (Days)	Sex	Nerves and Plexuses Involved
VQ–1908—C–13	204	Cockerel	Right and left sciatic
VQ–1908—C–14	117	Cockerel	Right sciatic and left brachial

Neurolymphomatosis did not occur in the 15 chickens produced by hen VQ–1803 and rooster VQ–1847, or in one chicken resulting from the crossing of hen VQ–1908 with rooster VQ–1870. Hen VQ–1908 and rooster VQ–2241, however, gave 14 chickens two of which showed symptoms of the disease after 204 and 117 days, respectively. Hen VQ–1908 showed no infiltrations in the ovaries, nor rooster VQ–2241 in the testes. The hatchability from Mating 2 was 69.76 percent and the percentage of neurolymphomatosis was 6.66.

TABLE 14. — THE TRANSMISSION OF NEUROLYMPHOMATOSIS THROUGH THE EGG

Mating 3. Roosters showing pathological cells in their semen, mated to hens with follicular fluids free of the cells.

Hen No.	Rooster No.	Number of Eggs Laid	Chickens		
			Hatched	Normal	Paralyzed
VQ–1877	VQ–2214	45	37	37	0
VQ–1987	VQ–1994	6	5	5	0
VQ–1988	VQ–1994	11	6	4	1

Necropsy Report on Birds in Mating 3

Bird No.	Nerves, Plexuses, and Organs Involved
Hens:	
VQ–1877	Right and left brachial
VQ–1987	Right ciliary, coeliac, and ovary
VQ–1988	Right lumbo-sacral and vagi
Roosters:	
VQ–2214	Coeliac, testis, and proventriculus
VQ–1994	Coeliac and testis

Only one chicken from these matings showed symptoms and lesions of neurolymphomatosis and that resulted from the mating of hen VQ–1988 with rooster VQ–1994. The symptoms appeared 150 days after the chicken hatched.

The testes of rooster VQ–2214 were involved, but the chickens produced by mating to hen VQ–1877 did not develop neurolymphomatosis. The results indicate that neurolymphomatosis may have been transmitted through the egg to one chicken by rooster VQ–1994; but since rooster VQ–2214 failed to transmit the disease, the evidence is not as conclusive as it probably would have been if a larger group of birds had been used in the experiment.

Hen VQ–1987 began to moult and ceased to lay on the tenth day of the experiment. A week later neurolymphomatous cells appeared in the follicular fluid and remained for two months or until no more fluid could be obtained for examination. Before the moult occurred this hen laid six eggs from which five healthy chickens hatched. Necropsy revealed infiltration of the coeliac plexus and ovary. Probably this bird was thrown out of production by a moult before the conditions were favorable for the transmission of the disease through the egg; and since the disease is progressive, the infiltration continued until the ovary was completely involved and was therefore unable to function when the hen had finished moulting.

In Mating 3 the hatchability was 77.42 percent, and the percentage of neurolymphomatosis 2.08.

TABLE 14.—THE TRANSMISSION OF NEUROLYMPHOMATOSIS THROUGH THE EGG

Mating 4. Controls — no pathological cells in seminal or follicular fluids.

Hen No.	Rooster No.	Number of Eggs Laid	Chickens Hatched	Chickens Normal	Chickens Paralyzed
VQ–1919	VQ–1875	51	47	47	0
VQ–1920	VQ–1874	38	33	33	0
E–1025	O–1063	—	17	11	6

Necropsy Report on the Control Birds (Mating 4)

Bird No.	Nerves and Organs Involved
Hens:	
VQ–1919	None
VQ–1920	None
E–1025	Left ciliary, ovary
Roosters:	
VQ–1875	None
VQ–1874	None
O–1063	Left ciliary

The first two matings, VQ–1919 x VQ–1875, and VQ–1920 x VQ–1874, produced 89 eggs from which 80 healthy chickens were hatched.

Up to this time no evidence had been secured to indicate that hens and roosters with neurolymphomatosis of the eyes transmitted the disease to their chickens as long as the ovaries and testes were unaffected. Hen E–1025, in the third mating, was three years old and the ciliary nerves of the left eye were paralyzed so that the bird was totally blind in this eye. This hen was on the 1934 and 1935 experiment for the transmission of neurolymphomatosis through the egg (Table 10). While on this experiment she laid 200 eggs from which 120 healthy chickens were hatched, and none of them showed symptoms of neurolymphomatosis over a period of eight months. In this control experiment she was mated to a yearling rooster, O–1063, with the same affection of the left eye. Unfortunately her egg record for this last mating was not kept; but it is known that 17 healthy chickens were hatched, six of which developed neurolymphomatosis over a period of four months. Three of the chickens had neurolymphomatosis of one eye, two of both eyes, and one of the mesenteric nerve. At necropsy hen E–1025 showed a small neurolymphoma embedded in the ovary, and the coeliac plexus was unaffected. This ovarian lesion may have been responsible for the transmission of the disease to the chickens, although at no time during the course of this investigation were neurolymphomatous cells found in the follicular and seminal fluids of any of the controls. The fact that five of the six affected chickens had neurolymphomatosis of the ciliary nerves like the parents may indicate that some unknown inheritable factors operated in addition to the actual transmission of the pathological cell through the egg.

These matings produce further evidence to indicate that neurolymphomatosis is transmitted through the egg to the chick, and that cells indistinguishable from the pathological cells in neurolymphomatosis sometimes appear in the follicular and seminal fluids of affected birds, especially when the infiltration is present in the ovaries and testes. However, evidence is lacking to indicate that these cells transmit the disease to either mate at copulation.

The Infiltration of Ovules with Cells Indistinguishable from Neurolymphomatous Cells from Ovarian Tissue

The ovule embedded in the ovary of the hen appears to be surrounded by a layer of endothelial cells as shown in Figure 6. In some birds neurolymphomatous cells infiltrate this layer and in others they do not. Resistance to neurolymphomatosis may exist in this layer of cells. However, the methods of resistance to disease are so little understood that it is best for the time being to state this as a suggestion rather than as a fact. It was not possible to make a thorough histological study of the ovaries of all the birds in these experiments. But those that were picked at random indicate that neurolymphomatous cells from the coeliac plexus frequently infiltrated the tissue of the ovary and less frequently the ovules embedded in this tissue. This has been known for several years, and Gibbs (1934) stated that "The pathological cell responsible for these malignant growths (neurolymphomatosis) occasionally develops such invasiveness that any or all tissues are affected." The foundation of the present investigation lies in the findings of earlier studies which have never been published in full.

The results of the histological studies showing infiltration from the ovary to the ovule are reported in Table 15.

TABLE 15. — INFILTRATION OF NEUROLYMPHOMATOUS CELLS FROM THE OVARY TO THE OVULE

Hen No.	Reported in	Infiltration			Chickens Developing Neurolymphomatosis
		Coeliac	Ovary	Ovule	
M– 355	Table 7	+	+	+	1
M– 553		+	+	+	1
M–1389		+	+	+	2
M–2352		0	0	0	0
H–1492		+	+	+	4
M– 68		+	+	+	1
M–1790		+	+	0	1
N– 49		+	+	+	2
M–3065		+	0	0	0
M–1992		+	+	0	1
F– 286	Table 10	+	+	+	10
F– 1095		+	+	+	9
F– 1488		+	+	0	0
M– 986		+	+	+	1
F– 1064		+	+	+	3
F– 24		+	+	+	1
F– 1096	Table 13	0	0	0	0
F– 1478		0	0	0	0
F– 1493		0	0	0	0
F– 286–C– 35	Mating 1 Table 14	+	+	+	2
F–1095–C–128		+	+	+	2
VQ–1803	Mating 2	+	0	0	0
VQ–1908		+	0	0	2
VQ–1987	Mating 3	+	+	0	0
VQ–1988		0	0	0	1

On account of the rigid selection of the ovaries reported in Table 15 it would appear that neurolymphomatous infiltration into the ovaries and ovules was common, and it may be that it is; but infiltrated ovaries and ovules certainly were not as easy to find as the data in this table would indicate. It should be borne in mind that the birds were carefully selected for these experiments from a greater number that were rejected, and then no ovary was studied histologically unless it appeared to be infiltrated on macroscopic examination.

On comparing the results of the histological studies with the transmission experiments, it was found that 13 of the hens, M-355, M-553, M-1389, H-1492, M-68, N-49, F-286, F-1095, M-986, F-1064, F-24, F-286-C-35, and F-286-C-128, showed infiltration of neurolymphomatous cells into one or more ovules, and the disease appeared in one or more of their chickens. Neurolymphomatous cells were not found in any of the ovules from M-1790, M-1992, VQ-1908, and VQ-1988, yet each produced at least one paralytic chick.

The coeliac plexus and ovaries of F-1488 and VQ-1987 were infiltrated with neurolymphomatous cells, but no paralytic chickens were produced by them. The coeliac plexus only was involved in hens M-3065, VQ-1803, and VQ-1908, and neurolymphomatosis did not occur in the chickens from the first two; but VQ-1908 had two affected chickens, and in some way which is not understood pathological cells were repeatedly found in the follicular fluid.

Chicken Embryos Inoculated With Living Neurolymphomatous Cells

Since neurolymphomatosis appeared to be transmitted naturally through the egg, an attempt was made to transmit it artificially. For this experiment 250 eggs were selected by candling to ensure living embryos, and divided into five groups of 50 eggs each. A piece of the shell was removed and two drops of a sterile suspension of living neurolymphomatous cells in physiological saline solution dropped upon the embryo. The shell was replaced and sealed into position with plaster of Paris. The results of this experiment are recorded in Table 16, and indicate that neurolymphomatosis may be transmitted in this way until the embryos are about 15 days old. The fact that infection did not occur after this age does not necessarily mean that the nervous system is more resistant to the disease, because it may be that as the embryo grows it is more protected from infective agents introduced beneath the shell.

Table 16. — Results of Inoculating Chicken Embryos with Living Neurolymphomatous Cells

Age of Embryo at Inoculation (Days)	Chickens	
	Affected	Unaffected
1	20	30
5	21	29
10	15	35
15	1	49
20	0	50

Living neurolymphomatous cells were introduced into the yolks of 100 eggs which were immediately placed in the incubator. In this experiment a small hole was drilled through the egg shell and the cells introduced by means of a sterile hypodermic needle and syringe. The hole was sealed with plaster of Paris. Neurolymphomatosis was not transmitted to any of the chickens in this way, since 65 of these were raised to eight months of age without any indications of disease.

SUMMARY AND CONCLUSIONS

The Leukotic Diseases

1. Erythroleukosis and myeloleukosis are filterable virus diseases, and the filterable agents are contained in the blood stream independent of the cellular elements. Chickens under a year old are more susceptible than older birds. Predisposing factors appear to be mites, warm weather, and overcrowding.

2. An outbreak of monoleukosis is reported as distinct from erythroleukosis and myeloleukosis.

3. Lympholeukosis is due to a histogenous cell identified by the vesicular arrangement of the chromatin of the nucleus. It is usually found infiltrating the tissues of the liver and spleen, and free in the portal blood of affected chickens. The living lympholeukotic cell is resistant to vital stains such as trypan blue, but the dead cell readily absorbs trypan blue. Lympholeukosis was transmitted from diseased to healthy chickens by inoculating portal blood containing large numbers of the living cells directly into the blood stream or the abdominal cavity.

Neurolymphomatosis

4. Neurolymphomatosis or avian paralysis is due to a histogenous cell indistinguishable from that occurring in lympholeukosis, except that it has a special predilection for the nervous system, and under conditions not very well understood, it may invade other adjacent tissues. Chickens inoculated in the nervous system with living cells developed neurolymphomas distally to the point of inoculation in the nerves of the limbs.

5. The evidence indicates that the neurolymphomatous cell was transmitted from the hen and possibly from the rooster to the chicken through the egg. The exact method by which the egg is affected was not determined, although neurolymphomatous cells were found infiltrating ovules in affected hens and cells indistinguishable from them were found in the semen of affected roosters and the follicular fluid of diseased hens. The ovaries and testes of active transmitters were found at necropsy to be infiltrated with neurolymphomatous cells, and no hen or rooster was incriminated in this study as a transmitter that did not show such infiltration of the reproductive organs at some time.

6. Symptoms appeared in affected chickens in from 2 weeks to 10 months. The average period for the 66 birds in this study was 188.85 days or about 6 months.

7. During the course of these observations and experiments, evidence was secured which indicates that hereditary factors involving resistant and susceptible birds were found in certain forms of neurolymphomatosis, particularly in the infiltration of the ovules of the ovary and the nerve of the eye.

8. In conclusion it should be pointed out that the experiments reported in this bulletin were directed toward a study of those forms of neurolymphomatosis which affect the ovary and testes, and of the methods whereby the disease is transmitted through the egg. Transmission through the egg, however, may not be the only way or even the most important way in which the disease is spread.

REFERENCES

1935. Burrows, W. H., and J. P. Quinn. A method of obtaining spermatozoa from the domestic fowl. Poultry Sci. 14 (4): 25.

1932. Cox, H. R., and R. R. Hyde. The physical factors involved in ultrafiltration. Am. Jour. Hyg. 16: 667-728.

1928. Doyle, L. P. Neuritis or paralysis in chickens. Jour. Am. Vet. Med. Assoc. 72 (N.S. 25 (5)): 585-587.

1929. Doyle, L. P. Neuritis or paralysis of fowls. Poultry Sci. 8 (3): 159-160.

1934. Downham, K. D., and C. Crompton. Observations upon neuritis in fowls. A quick method of diagnosis by means of nerve smear preparations. Vet. Jour. 90 (12): 505-507.

1935. Emmel, M. W. The etiology of fowl paralysis, leukemia and allied conditions in animals. Fla. Agr. Exp. Sta. Bul. 284.

1936. Emmel, M. W. Hemocytoblastosis and its relation to the development of fowl paralysis and fowl leukemia. Jour. Am. Vet. Med. Assoc. 88 (N.S. 41 (1)): 45-50.

1914. Evans, H. M., and W. Schulemann. The action of vital stains belonging to the benzidine group. Science 39 (1004): 443-454.

1936. Fenstermacher, R. Lymphocytoma and fowl paralysis. Jour. Am. Vet. Med. Assoc. 88 (N.S. 41 (5)): 600-613.

1931. Furth, J. Erythroleukosis and the anemias of the fowl. Arch. Path. 12: 1-30.

1935. Furth, J. Lymphomatosis in relation to fowl paralysis. Arch. Path. 20: 379-428.

1934. Gibbs, C. S. Preliminary studies on neurolymphomatosis and some more or less related diseases. Mass. Agr. Exp. Sta. Bul. 308.

1936. Gibbs, C. S., and C. G. Johnson. Differentiation of the pathological cells in neurolymphomatosis from lymphocytes of the blood of chickens. Mass. Agr. Exp. Sta. Bul. 327: 77-78.

1934. Johnson, E. P. The etiology and histogenesis of leucosis and lymphomatosis of fowls. Va. Agr. Exp. Sta. Tech. Bul. 56.

1935. Jordan, H. E. The role of the lymphocyte in blood formation. Science 82 (2136): 539.

1929. Pappenheimer, A. M., L. C. Dunn, and V. Cone. Studies on fowl paralysis (neurolymphomatosis gallinarum). 1. Clinical features and pathology. Jour. Exp. Med. 49 (1): 63-86.

1932. Patterson, F. D., H. L. Wilcke, C. Murray, and E. W. Henderson. So-called range paralysis of the chicken. Jour. Am. Vet. Med. Assoc. 81 (N.S. 34 (6)): 747-767.

1936. Patterson, F. D. Fowl leukosis. Jour. Am. Vet. Med. Assoc. 88 (N.S. 41 (1)): 32-43.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
3m 3-'37. No. 42

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 338 December, 1936

The Effect of Processing on Vitamins in Fruits and Vegetables

A Review

By C. R. Fellers

Among the food constituents necessary for life are the vitamins. This bulletin reviews the vast amount of research being conducted on the occurrence and stability of the vitamins in foods. By the application of certain principles and practices in the distribution and processing of fruit and vegetable products, the several vitamins may be better conserved in the interest of a more adequate diet and improved health.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE EFFECT OF PROCESSING ON VITAMINS IN FRUITS AND VEGETABLES
A REVIEW[1]

By C. R. Fellers Research Professor of Horticultural Manufactures

The public is nutrition conscious. The discovery of the vitamins as essential factors in human and animal nutrition has led to much confusion and misinformation in the minds of many persons. In time, as science slowly unfolds the true story of the vitamins in their relations to health and disease, the facts as to sources, stability, requirements, and functions of these substances will be clearly defined. That time has not yet arrived. This bulletin sets forth in the form of a review of investigations the present status of our knowledge on the stability of vitamins A, B, C, D, E, and G in fruits and vegetables when subjected to varied conditions of storage, freezing, drying, and canning. No attempt is made to present a monograph on the subject, and special attention has been paid to the more recent investigations. It is hoped that the facts presented will serve to give a clearer concept of the effect of certain environmental factors on the vitamins. Frozen, canned, and dried fruits and vegetables are very widely consumed and form a considerable proportion of the human dietary. The retention of the vitamins in these processed foods is of the greatest health interest. This bulletin sums up investigations carried on in other laboratories, as well as extensive studies in this field of research at this station.

VITAMIN A

Effect of Maturity and Storage on Vitamin A

Jones and Nelson (100) found that stage of maturity of tomatoes had no effect on the vitamin A content. Green tomatoes produced as good growth in rats as mature. Morgan and Smith, on the other hand, found much greater amounts of this vitamin in ripe than green tomatoes (154). House, Nelson, and Haber (91) found a lesser amount of A in full-sized green tomatoes than in the fully ripened fruit. However, the A content was the same regardless of whether the fruit was picked ripe or artificially ripened. Bleached leaves of celery, cabbage, and lettuce were much lower in A than the green outer leaves. Kohman, Eddy, and Gurin (108) showed that bleaching destroyed 50 percent of the A in celery. Potatoes and carrots lost no A during several months' storage, according to Richardson and Mayfield (174). Swanson, Nelson, and Haber (207) found no loss in storing sweet potatoes for several months at ordinary temperatures. Morgan and Field (147) showed no loss of A in peaches, prunes, and apricots at 32° F. Manville and Chuinard (131) proved that some A was lost in pears on prolonged storage. Manville, McMinis, and Chuinard (132, 133) showed that prolonged storage of apples was less destructive to vitamin A than to C.

---

[1] Read at the 92nd Meeting of the American Chemical Society, Division of Agricultural and Food Chemistry, September 10, 1936, Pittsburgh, Pa.

Fraps and Treichler (66) found that A in corn, alfalfa, and feeds, as well as in dried whole milk, gradually decreased in storage. They (67) ascertained that brown-eye peas and alfalfa meal lost 50 percent in eleven months, dried green sweet peppers lost 80 percent in nineteen months, dried whole milk lost 60 percent in nine months, and whole or ground yellow corn lost 30 to 50 percent in six months. Alfalfa hay lost 24 percent of its vitamin A in four months' storage, while sweating in the stack caused a loss of 33 percent, as determined by Woods, Atkeson, Wellhousen, and Johnson (225).

Dried spinach lost 70 percent of its vitamin A in 15 months' storage in diffused light, according to Quinn, Hartley, and Derow (169). They also showed that ultra-violet light destroyed the vitamin A in carrot extract in 3 to 5 hours.

Storage of canned tomatoes for three years caused no change in A content, according to Nelson, Swanson, and Haber (159). On the other hand, Langley, Richardson, and Andes (117) found a six months' storage period was injurious to the A content of canned carrots. Canned pineapple was shown to retain well its content of vitamins A, B, G, and C, according to Guerrant, Dutcher, Tabor, and Rasmussen (74). Hanning (79) found that vitamins A and B were well retained in canned strained vegetables. In general, storage of canned foods has not been found to reduce the vitamin A materially.

Sherman and Smith (193) state that vitamin A in oils stored in the dark is fairly stable. Similarly, Drummond, Coward, and Watson (41) found that butter in storage retained practically all of its A.

Effect of Freezing on Vitamin A

Freezing caused no injury to the vitamin A in mangoes, according to Hermano and Aguila (85). Peaches suffered no loss of A by freezing as found by Newton (160). On the other hand, Kramer (114) and Kramer and Agan (113) found only slight decrease in A on freezing or canning cherries. Freezing, with or without air removal, caused a rapid loss of A in grapes. Fellers, Young, Isham, and Clague (64) found that quick freezing was not injurious to the A in asparagus. This laboratory also found no differences in the A content of fresh and rapidly frozen blueberries, cranberries, peas, lima beans, and sweet corn. Similarly, Batchelder, Miller, Sevals, and Starling (8) found that blackberries, though a poor source of Vitamin A, retained it after freezing.

Vitamin A in ice cream mix, butter, and eggs is unaffected by freezing, according to Blackfan (12).

Effect of Heat on Vitamin A

Scheunert (183) states "Cooking and sterilizing of vegetables and fruits does not appreciably influence their vitamin A content." Similarly, Blackfan (12) states, "There is little if any destruction of vitamins A, D, E, and G in the canning of fruits and vegetables." Douglass and Richardson (40) found that neither oven nor pressure canning had any effect on A. Kohman (106) ascribed losses of vitamin A during canning and allied operations to oxidation rather than to heat itself.

Nelson, Swanson, and Haber (159), Kohman, Eddy, and Zall (111), and this laboratory (54) have shown that canning had little or no effect on A in tomatoes. According to Coward and Morgan (26), carrots, runner beans, and cabbage lost no vitamin A on boiling. The blanching and boiling (45 minutes) of turnip greens and collards were not harmful to A, as indicated by Newton (160). Kohman, Eddy, and Gurin (108) showed that canning preserved the vitamin A of turnip greens, and also of grapefruit and prunes (109). Cooking and canning of spinach were not injurious to the vitamin A, according to Hoff (90). Hanning (81) obtained similar results with spinach, green string beans, peas, carrots, and tomatoes. Langley, Richardson, and Andes (117) showed that, while cooking was slightly destructive to the vitamin A in carrots, canning was not destructive. Crist and Dye (28) found that raw, cooked, and canned green asparagus gave the same growth gains in rats, indicating the same A content in all three products. Sherman and Smith (193) report that no significant differences have been found in the A content of fresh and canned peas and spinach. Eddy, Kohman, and Carlsson (47) found no loss in A in cooking or canning spinach. Hume (93), Campbell and Chick (17), and Delf (37) found no loss in A on cooking cabbage. Autoclaving of dried sweet potatoes, chard, carrots, and squash did not lower the A content of these vegetables, as observed by Steenbock and Boutwell (202). Miller (139) could detect no loss of A in the canning of pineapple.

It is interesting to note that Scheunert and Wagner (186) found that the A in butter was not noticeably reduced by baking or roasting, but heating in an open pan at 350° to 392° F. caused serious, though not complete, loss. In making butter cookies, Parsons, Stevenson, Mullen, and Horn (163) found a 20 to 25 percent loss in vitamin A. Waltner (217) substantiated these findings and determined that milk lost little A on heating. Whipple (222) reported a small loss in A on cooking oysters. Margaillan (134) stated that the refining process robbed olive oil of 80 percent of its vitamin A.

Effect of Drying on Vitamin A

Among the many investigators who have shown that drying alfalfa, hay, or other green feeds is destructive to the vitamin A are Russell, Taylor, and Chichester (178), Fraps and Treichler (66), and Hauge and Aitkenhead (84). In some cases 80 percent or more of the carotene is lost in sun-drying. Artificial dehydration is much less destructive to vitamin A.

Morgan, Field, Kimmel, and Nichols (149) found that dehydration preserved the vitamin A of figs better than sun-drying. Similar results with grapes were reported by Morgan, Kimmel, Field, and Nichols (152). Sun-drying destroyed all the A whether or not the fruit was treated with sulfur dioxide. Dutcher and Outhouse (45) reported the almost complete loss of A in raisins. Morgan and Field (147) found that apricots lost more A than prunes and peaches in dehydration, while sun-drying was destructive to A in all the fruits. SO_2 exerted much more protective action against loss of A in dehydration than in sun-drying. Lye-dipping of prunes caused no loss of A. Smith and Meeker (198) demonstrated that drying and processing were destructive to the A in dates; while Morgan (145) reported that artificial ripening, fumigation, and pasteurization showed no effect on A content. Fraps and Treichler (68) found that, when dried in vacuum, carrots lost 80 percent, sweet potatoes 29 percent, and canned spinach 65 percent of their original vitamin A. There is a marked loss of vitamin A in drying cabbage and other vegetables, as reported by Delf and Skelton (38), Steenbock and Gross (204), and Steenbock and Sell (206).

A few experiments show some degree of retention of vitamin A in dried foods. Thus, Morgan and Francis (150) and Steenbock and Gross (203) showed that pumpkin, sugar beets, beets, parsnips, and potatoes could be carefully dried so as to retain a substantial part of their original vitamin A.

Effect of Other Factors on Vitamin A

When pickled in a salted rice bran paste, Chinese cabbage lost 50 percent of its vitamin A, according to Miller and Robbins (140). Norris (161) showed that irradiation of cod liver oil for 8 hours destroyed all the vitamin A.

Summary on Vitamin A

It would appear that at freezing and low storage temperatures little loss occurs, but at ordinary temperatures there is a gradual loss in carotene and vitamin A in green vegetables. Drying is decidedly harmful in most products, although, unless prolonged, a considerable percentage of the A is retained. Sun-drying is decidedly more injurious than dehydration. Sulfur dioxide treatment of dried fruits aids in conserving the vitamins A and C. In general, rapid cooking and usual home and commercial canning methods do not materially injure vitamin A. It is well recognized that oxidation rather than heat is the destructive factor. Any means of avoiding oxidation and enzyme activity will aid in conserving the vitamin in food preservation processes.

With the development of rapid, reasonably accurate chemical methods for carotene determination in plant tissues, greater clarification of the effects of environmental factors on vitamin A in fruits and vegetables may be confidently expected in the near future. For excellent summaries of vitamin A investigations in the past twenty-five years, reference should be made to the reviews by Karrer and Wehrli (101), McCollum (125), and Harris (82).

VITAMIN D

The usual natural sources of vitamin D are milk, butter, eggs, and fish oils. It is not found in abundance in fruits and vegetables, but occasional references to its presence have been noted. Mushrooms contain a small amount of D, according to Scheunert and Reschke (184). Coffin (25) reported small amounts of D in many common foods including vegetables. Weatherby (219) claimed that some D was present in avocados; Morgan (145) found a little in dates; and Cultrera (29) reported D in tomatoes. That vitamin D is present in rhubarb even after cooking is attested by Barshai, Fomin, and Shvatshko (6). Munsell and Kennedy (156) found no D in lettuce. Morgan (146) showed that the sun-drying of prunes, grapes, peaches, and apricots produced no increase in the negligible D content of these fruits In China, Lo (122) found the mottled gram bean to be a fair source of D.

There are few data bearing on the effects of drying, freezing, or canning processes on vitamin D. However, it is well known that the D is retained in canned salmon, sardines, and similar products. Moore and Moseley (144) found an appreciable amount of D in canned shrimp. The vitamin is stable to heat and moderately stable to oxidation. Steenbock, Scott, and Irwin (205) showed that vitamin D when added to boiling doughnut fat is rapidly destroyed. However, irradiated or other vitamin D milks may be pasteurized without loss of vitamin D. Kohman, Sanborn, Eddy, and Gurin (112) have recently stated that the calcium in canned vegetables seems to be very readily available and they believe certain canned foods contain appreciable and significant amounts of vitamin D which cannot be measured by present assay methods. McCay (124) has taken exception to these conclusions. There seems to be no doubt as to the presence of a small amount of vitamin D in corn silage, fresh grass, and hay, as reported by Hodgson and Knott (89), Rygh (179), and many others.

In summarizing the existing data on vitamin D in fruits and vegetables, it seems safe to assume that no marked losses occur in storage, freezing, or canning. Oxidation is destructive. There is need for new research on vitamin D in fruits and vegetables, and its relationship to mineral metabolism in animals and humans. The D factor may prove to be more important than is now commonly conceded. Of more than passing interest are the results of Kohman, Eddy, and Gurin (109), who successfully raised five generations of rats and three of guinea pigs on diets consisting only of canned foods. Such results would indicate that by selection, man's dietary needs can be fully met by preserved foods, and of course this means all the vitamins.

VITAMIN E

It was only twelve years ago that a specific vitamin essential for reproduction was definitely shown to exist. A good survey of existing knowledge on this vitamin has been made by the British Medical Research Council in their book "Vitamins, A Survey of Present Knowledge" (137). Wheat germ oil is one of the richest sources, but there seems to be a very general distribution of vitamin E in leafy vegetables, cereals, meats, dairy products, and eggs. Largely because of assay difficulties, only relatively few foods have been carefully studied for their content of vitamin E. The richest natural sources of the vitamin are green leaves and the embryos of seeds. It is absent in the endosperm of cereals. Vegetable oils contain, as a rule, small but significant amounts of this vitamin. Sherman and Smith (193) quote experiments to show that dried lettuce leaves, tea, and various dried seeds retained their vitamin E unimpaired. Both oranges and bananas contain E in small amounts.

Vitamin E appears to be remarkably stable to heat, hydrogenation, saponification, and distillation. Under some conditions it is susceptible to oxidation, particularly in fats and oils exposed to air. While E is fat-soluble, a small amount of the vitamin can be extracted with water. Kohman (106) cites several experiments to show that vitamin E is very stable to boiling, cooking, and even autoclaving. Surely, usual canning processes would have no effect. Similarly, though no studies have been reported, freezing and cold storage are probably without effect.

The human body is able to store and hold in reserve a surplus of vitamin E. Blackfan (12) in reporting for his Committee on Growth and Development of the Child, at the White House Conference in 1932, states, "There is no clinical evidence that there is a vitamin E problem so far as humans are concerned."

VITAMIN B (B_1)

Effect of Freezing and Storage on Vitamin B (B_1)

The antineuritic vitamin is well distributed in plant materials, though in many fruits in rather limited amounts. Vitamin B is water soluble and may be easily leached from plant tissues, especially with the aid of heat. Often referred to in the past as the "heat-labile vitamin B," it appears that this vitamin is much more stable than was previously thought. Von Euler (50) in 1936 contributed a good concise summary of recent studies of the water-soluble vitamins.

Langley, Richardson, and Andes (117) found no loss in B in carrots during 4 months' cellar storage. They reported that canned carrots lost vitamins A, B, and C after 6 months' cellar storage. Similarly, Douglass and Richardson (40) and also House, Nelson, and Haber (92) observed no loss in the common storage of carrots. They also found no differences in B content of field-grown and hothouse lettuce and tomatoes. As a result of limited data, Jones and Nelson (100) reported an apparent loss of B in storage of tomatoes. Treatment with ethylene gas was without effect. Daniel and Munsell (32) reported that Malaga and Sultanina grapes were fair sources of vitamin B, but very little of the vitamin was present in two brands of grape juice tested. Vacca (214) found no B in Italian grapes.

The only reference which was found on the effect of freezing on vitamin B is by Morgan, Kimmel, Field, and Nichols (152). Their work indicated a rapid loss of B regardless of whether or not the gases had been removed from Sultanina grapes and raisins. Much more research is urgently needed to ascertain definitely the stability of vitamin B to the freezing, storage, and the defrosting of foods.

Effect of Drying on Vitamin B (B_1)

Dried prunes contain 0.8 to 1.0 Sherman unit of vitamin B per gram, as determined by Morgan, Hunt, and Squier (151). Morgan (146) observed some loss of B in the drying of prunes, apricots, grapes, and peaches. The use of sulfur dioxide did not conserve the vitamin. Figs were shown to contain 2.5 to 7.1 units of B per gram. Sulfuring the figs reduced their content of vitamin B, according to Morgan, Field, Kimmel, and Nichols (149). Kline, Keenan, Elvehjem, and Hart (104) and Keenan and Kline (102) found that exposure to dry heat at 212° F. had no effect on vitamins B or G. In fact, B was uninjured when kiln-heated at 248° F. for 24 hours. Under similar conditions G was destroyed. Sherman and Spohn (194) found that B was more easily destroyed by heat in liquid than in dry milk. However, Dutcher and Francis (44) found no loss in evaporated milk.

Fomin and Makarova (65) found that B was lost in acid-preserved spinach, but vitamin C was not.

Effect of Heat on Vitamin B (B_1)

Newton (160) found that both raw and canned turnip greens contained 0.5 unit per gram. No vitamin B was lost by boiling the greens. However, Munsell and Kifer (157) reported a 50 percent loss of B in cooking broccoli. Scheunert and Wagner (185) found no loss on boiling for 30 minutes or in pressure cooking for 10 minutes. The vegetables used were brussels sprouts, cabbage, spinach, and potatoes. Scheunert (182) claimed that B was not greatly injured by either boiling or canning. Still, Douglass and Richardson (40) found that oven canning destroyed a part of the B of carrots. Pressure cooker canning was without effect. Langley, Richardson, and Andes (117) found a noticeable loss of B in cooking and a decided loss in canning carrots. Van Veen (215) discovered that 50 percent of the B of unpolished rice was retained after washing and steaming. Polished rice lost much B by washing but none by steaming. Hoff (90) reported that cooking was more destructive to B than canning.

Daniels, Giddings, and Jordan (34) ascertained that both heat and oxidation are harmful to the vitamin B of milk. On bubbling air through milk, or on boiling, no loss in vitamin B was obtained by Spruyt and Donath (201). In canning animal tissues, Elvehjem, Sherman, and Arnold (49) found that as much as 80 percent of the vitamin B could be lost. In cooking oysters, Whipple (222) observed no loss of B.

The British Medical Research Council (137) states, "Continuous heating of foodstuffs at 212° F., however, leads to some loss of vitamin B. In preserving and canning foodstuffs the temperatures employed are frequently much higher than 212° F., and canned foods of all descriptions may contain very little or no vitamin B (B_1) and, as a practical rule, should therefore be regarded as free from it unless they have been especially investigated and found to contain it." Many of the earlier experiments on effect on vitamin B of environmental factors are invalidated because of inability to differentiate the several factors involved in the B complex. Kohman (106) has summed up a number of investigations conducted previous to 1927 on the vitamin B complex. He states that vitamin B is generally regarded as being less affected by oxidation than the other vitamins. Commercially canned tomatoes, canned pineapple, peas and peaches lose no appreciable amount of vitamin B (complex) in the canning process.

Effect of Acidity

Sherman and Burton (191) showed that by decreasing the acidity of tomato juice from pH 4.28 to 5.2 the rate of destruction of vitamin B was increased. This destruction was seemingly not influenced by oxidation and the loss was presumably catalyzed by hydroxyl ions. On both sides of neutrality, the rate of destruction was a function of the medium in which the vitamin B was dissolved.

Summary on Vitamin B (B_1)

Generally speaking, vitamin B cannot be considered immune from at least partial destruction by drying, cooking and canning certain foods. In the words of the White House Conference on Child Health and Protection (12). "The antineuritic fraction of B is appreciably destroyed, but less so in fruits than in vegetables for the fruit acids tend to stabilize the vitamin and also make it possible to sterilize the fruit at a lower temperature and for a shorter period than for non-acid vegetables."

VITAMIN G (B_2)

Until of late, very few studies have been made on the occurrence or stability of vitamin G in fruits and vegetables. However, with the clearer differentiation of G from the other factors of the vitamin B complex, renewed interest has sprung up.

Since Goldberger's classic work on the pellagra-preventive factor in foods, it has been fairly well established that vitamin G is widely distributed in the plant and animal kingdoms. Sebrell (187) has prepared a table showing the pellagra-preventive values of various foods. Munsell (155) has admirably summed up the relation of G to the other B-complex factors.

Hunt, Record, Wilder, and Bethke (95) found that the G content of hay decreased with maturity, that rain may remove as much as 50 percent of this vitamin (94), and that a high G content is associated with a rich green color.

Day and Darby (36) showed that pears contained five times as much G as apples, but avocados were richest of all the fruits examined. Douglass, Halloway, Williams, and Garrison (39) reported the B value of Bosc pears at 0.22 unit per gram. Roehm (176) found that fresh grapefruit pulp was a fair source of G. Morgan (146) ascertained that prunes lost no G during drying. The G content of dried prunes was established at approximately 1.2 units per gram by Witt and Poe (223). Hanning (80) found that canned, strained tomatoes contained 0.25 unit, beets 0.12, string beans 0.3, spinach and peas 0.4. Pineapple juice contained nearly 0.1 unit per gram. Poe and Gambill (167) determined the average G content of several tomato juices as 0.21 unit per gram. Fellers and Isham (57) found only traces of G in fresh or canned cranberries. Munsell and Kennedy (156) demonstrated from 0.24 to 1.18 units of G per gram of lettuce. Broccoli is also a good source of G according to Munsell and Kifer (157) and Roehm (176). However, cooking destroyed a part of the G content of this vegetable. On the other hand, Hoff (90) stated that the G in cooked or canned spinach was not seriously injured. Wheeler (220, 221), Sebrell, Wheeler, and Hunt (188), and Goldberger and Wheeler (72) all reported the presence of vitamin G in various canned foods such as chicken, haddock, salmon, peas, spinach, and turnip greens. Day (35) found that turnip tops contained four to six times as much G as the roots. Lo (121) showed that the cucumber was a good source of G. Krizenecky and Nevalonnyj (116) reported the presence of this vitamin in fermented vinegar.

The British Medical Research Council (137) states, "Its heat stability (vitamin B_2) is, however, only relative, depending largely on the reaction at which the heating takes place." For example, Guha and Chakravorty (75) found that the optimum reaction for extraction of G was at pH 5.0, while heating ox kidney for 15 minutes at pH 10.5 in water destroyed most of it. Halliday, Nunn, and Fisher (78), also Chick and Copping (20), observed that the inactivation of G increases rapidly with increasing alkalinity.

There has been no reported work on the effect of freezing on vitamin G, but it seems improbable that there would be any loss.

In summarizing the work on vitamin G, it is found that, although fruits and vegetables in general are rather poor sources of G, still it is very widely distributed. Furthermore, the preponderance of the existing data indicate that G is not seriously injured by the usual methods of food preservation such as drying, fermentation, freezing, and canning. Only in alkaline media or in long heat exposure in air is the G destroyed. It is, of course, water soluble and unless the juices of cooked fruits and vegetables are utilized, losses will occur.

VITAMIN C

Vitamin C, the anti-scurvy vitamin, is of particular interest in this review because fruits and vegetables are the principal sources of it. More researches have been reported on the effect of environmental factors on vitamin C than on all the other vitamins combined. The writer, without claiming any degree of completeness in his literature search, collected 235 references — nearly all published since 1928. A literal avalanche of investigations is now being carried on since the discovery by Tillmans (209) of the rapid titration technic for the determination of vitamin C.

Vitamin C is important for another reason; namely, that since the body does not store the vitamin at all, it is necessary to continually replenish the supply. This makes it very desirable to know which foods carry C and which do not. It is likewise important to know whether the various methods of food preservation such as drying, freezing, canning, and cold storage adversely affect the C content of fruits and vegetables.

Because of the impossibility of covering the entire literature in this brief survey, the reader is referred to the summary compiled in 1927 by Kohman (106), to that of Sherman and Smith (193) in 1931, and to the Report of the British Medical Research Council (137) in 1932. A number of less complete surveys have also been published by Bacharach (2, 3), Smith (196), Scheunert (183), Priestly (168), Dutcher (43), Fellers (53) and Cowell (27).

Effect of Maturity and Storage on Vitamin C

Apples lost most of their C in 6 to 9 months according to Pelc and Podzimkova (164). Storage was also harmful to the C in oranges. Bracewell and Zilva (16) found no loss in C in 2 months in oranges and grapefruit. Todhunter (210,211) and also Batchelder (7) found that the losses in Delicious and some other apple varieties were approximately 17 percent in 3 months at 45° F., 25 percent in 6 months, and 50 percent in one year. Fellers, Cleveland, and Clague (55) determined that the loss of C in Baldwin apples stored at 36° F. for 4 to 6 months was 20 percent, and after 8 to 10 months, 40 percent. Van Leersum and Hoogenboom (120) found no loss of C in apples on storage. Smith and Fellers (197) found that the vitamin C content of 21 varieties of Massachusetts-grown apples stored from 1 to 3 months varied from 3 to 4 units per gram for Baldwins and Northern Spy to less than 0.5 unit for McIntosh, Delicious, and Jonathan. Zilva, Kidd, and West (233, 234, 235) found that 3 months' storage at 23° F. destroyed all the vitamin C of apples; at 14° F., 70 percent was destroyed; while at 23° to — 4° F., stored in vacuum, no loss occurred in 6 months. Bracewell, Kidd, West, and Zilva (15) observed no loss in C in Bramley's Seedling variety at 37.4° F. for 5 months. That immature Bramley's Seedling apples were as rich in C as mature fruits was shown by Zilva, Kidd, and West (234). Freezing storage had no effect on the vitamin C content of apples, but at 14° F. a loss was noted. Pears lost much of their C and A under prolonged storage, according to Manville and Chuinard (130, 131). Bacharach, Cook, and Smith (4) showed that losses in C occurred on storage of oranges, lemons, and tangerines. Murri, Onokhova, Kudryavtzeva, and Gutzevich (158) demonstrated losses in the vitamin C of Russian cranberries stored at 32° — 46.4° F. The berries left on the vines all winter also lost their C. Bogoliubova (13) found that storage of Russian cranberries for 4 months was not destructive to the vitamin C. She showed, however, that freezing (and probably subsequent defrosting) did destroy it. Fellers and Isham (57) found that storage at 36° F. had little effect on C of cranberries until after several months. However, Lavrov, Yanovskaya, and Yarusova (118) found that the juice of winter-stored mooseberries contained only traces of vitamin C, while preserved black currant juice had 333 units per liter.

Ranganathan (170, 171) found that spinach, tender amaranth, fenugreek, and coriander lost their C rapidly on storage. In spinach the loss in C paralleled the loss in acidity. Mangoes, chillies, and bitter gourds retained the C only so long as they remained green. Much C was lost if they ripened. Tressler, Mack, and King (213) observed a 50 percent loss in green spinach at ordinary temperatures in 3 days, and a total loss in 7 days. Langley, Richardson, and Andes (117), also Douglass and Richardson (40), found that winter storage of carrots had no injurious effect on C in 4 months, but after 6 months a loss of 66 percent was observed. Potatoes and carrots were stored until spring at cellar temperatures with an apparent increase in content of vitamins A and C. However, these vegetables lost more of these vitamins on cooking than was the case with fresh vegetables. McKittrick and Thiessen (126), and Thiessen (208) found that potatoes showed a loss of 50 percent of C in 6 to 8 months' storage. That home-grown fresh spinach is richer in C than shipped-in spinach, was proved by Wasson (218). Fellers and Stepat (62), and also Mack, Tressler, and King (128, 213) found that both peas and spinach lost their vitamin C rather rapidly at ordinary temperatures. In some cases peas lost 50 percent of their C in 3 days. Refrigeration was very effective in reducing losses of C from peas, lima beans, and spinach. Dunker, Fellers, and Fitzgerald (42) showed that sweet corn in the husk retains its C well for at least 36 to 48 hours with only slow loss after 3 days. Yarusova and Savel'eva (231) showed that white cabbage lost 30 percent of its C in 3 months' storage at 37.4° F. Similarly, Gould, Tressler, and King (73) demonstrated that Glory variety of cabbage lost 33 percent of its vitamin C in 42 days' storage at room temperature and

12 percent at storage temperatures of 46° — 48° F. However, at temperatures below 48° F., the cabbage lost one-third of its vitamin C in 84 days' storage. Tressler and Mack (212) showed that the vitamin C content of peas decreased with maturity. Snap beans, peas, and spinach rapidly lost their ascorbic acid if held at room temperature. Refrigeration reduced the losses. Izumrudova (98) ascertained that marked losses in the vitamin C of potatoes occurred during storage at 36.5° — 37.4° F. However, when frozen at 6.8° F. or lower, no loss occurred. According to Pett (165) potatoes lost vitamin C and glutathione rapidly at 59°, 50°, and 41°F. for 20 to 30 days, and then at a much slower rate. Yarusova and Mikhailina (230) found that 2 months' storage of potatoes at 24.8° to 39.2° F. had no effect on vitamin C activity. Garlic after storage contained no C according to Yarusova and Yanovska (232). That onions lose C on storage was shown by Shepilevska and Izumrudova (190). Woods (224) reported that immature potatoes were twice as high in C as mature ones and found no loss of C in storage in 3 to 8 months.

Jones and Nelson (100) showed that tomatoes increased somewhat in vitamin C as the fruit developed. Ethylene treatment had no effect. This was also proved by Clow and Marlatt (23) who determined that tomatoes picked green and allowed to ripen develop the full vitamin-C potency of the vine-ripened tomato. In this laboratory (127) work on tomatoes showed that the large green fruit is nearly as rich in C as the fully ripe. Storage of ripe tomatoes for 20 days had little effect on the C content so long as the fruit remained firm and free from decay. Ascorbic acid determinations on 98 varieties and strains of tomatoes in 1936 showed variations from 3.2 to 8.6 units per gram, with an average of about 5.5 units per gram.

Mack, Fellers, Maclinn, and Bean (129) found a marked loss in the vitamin C of orange beverages upon standing 20 to 44 hours at 75.20° F. This loss was much reduced at 40° F. In general, commercial orange drinks were only fair sources of vitamin C. Sah, Ma, and Hoo (181) reported that Chinese orange juices deteriorated rapidly in C content in storage. Orange crush, a commercial orange sirup, lost very little C in 3 months according to Koch and Koch (105). They found that in 3 months, even at cold storage temperatures, unstrained and unsweetened juice lost nearly all its C. Von Hahn (77) found German commercial orangeades of low C content. Hassan and Basili (83) reported that lime juice lost all of its C when stored in the refrigerator for 2 months. Vegetable juices, because of their high pH values and active oxidative enzyme systems, rapidly lose their vitamin C on short storage. For example, Rojahn and Wirth (177) found no C in commercial spinach, cucumber, horse-radish, carrot, and celery juices. Some vitamin A was present.

Cultrera (29) discovered that the use of sulfur dioxide in lemon juice at a concentration of 0.035 per cent, completely destroyed the vitamin C in 98 hours. The addition of 50 percent sugar to lemon juice as a preservative retained the C without loss for 180 days. Similarily, the preservation of raw black currants in sugar protected the C for at least 9 months, according to Shelesnii and Kanevska (189). However, they found cooked black currant jam entirely devoid of C. Yanovskaya (226) showed that the use of sulfur dioxide in black currant juice and cabbage juice had a preserving action on C. A special vitamin-C jam made with pine needle concentrate lost no C in four months' storage.

Effect of Drying on Vitamin C

In prunes, peaches, and apricots, Morgan (146) showed that the use of sulfur dioxide aided in retaining C to a limited extent. Gerstenberger, Smith, and Hacker (69) showed that orange concentrate, dried on lactose, lost no C after storage for 15 months. Morgan (146) and also Morgan, Field, and Nichols (148) showed a nearly complete loss of C in drying or dehydration of prunes and apricots. This laboratory found that evaporated apples, whether sulfured or not, retained less than 10 percent of their C. Pochino (166) found very little C in apple powder. Morgan, Field, Kimmel, and Nichols (149) showed that the small amount of C present in fresh figs was entirely lost in drying. Sulfur dioxide was of no value in retaining the vitamin C in white figs during the drying process.

Jancik (99) successfully dehydrated red and green peppers at low temperatures so as to retain a large percentage of their original C. Yarusova (227, 228) found that dried carrots and black currants lost much of their C during drying and after storage of the dried product. Dried or cooked onions and leeks contained practically no C, according to Matzko (136), although the fresh onion juice had about 0.33 unit per gram. He found only slight loss in rutabagas held in storage during the winter. Cabbage which had been sulfured and dried for 2 to 5 months still retained approximately 160 units of vitamin C per kilogram.

Green tea had considerable vitamin C when fresh but lost it upon drying, as found by Miura and Tsujimura (143) and also Mitchell (142).

The work previous to 1932 has been admirably summed up by the British Medical Research Council in its "Vitamins: A Survey of Present Knowledge" (137). "Dried vegetables have been repeatedly tried and found useless for preventing human scurvy and in this respect the results of the experimental work find abundant confirmation in the records of failure which have been preserved. Dried fruits have a distinct, though feeble, antiscurvy value in experimental trials. This result also coincides with human experience." The present literature review sustains this contention.

Freezing

Until recently there has been very little research relative to the effect of freezing fruits and vegetables on their vitamin C content. Closely allied to the effect of freezing is also the effect of frozen storage and defrosting, for nearly all foods are stored for varying periods of time and finally defrosted before eating. Fellers (52) in his summary on the effects of freezing on the nutritive and public health values of foods shows that freezing has only minor adverse effects on nutritive value. Some effects of freezing storage were noted in the experiments described under "storage" in this bulletin.

Cranberries were unaffected by freezing as noted by Fellers and Isham (57) and by Ivanov, Bukin, Borokhovich, and Povolotzkaya (96). According to Murri, Onokhova, Kudryavtzeva, and Gutzevich (158) freezing potatoes and apples had no effect on their C content. The slow thawing of potatoes caused a 60 percent loss in the C content. Zilva, Kidd, and West (233, 335) found that freezing apples was without effect on C. According to Morgan, Field, and Nichols (148) fresh apricots when frozen lost all their vitamin C unless the air was evacuated before freezing and the fruit stored in nitrogen; while the C of fresh prunes was not injured by freezing, even when the air was not removed. Both Shrader and Johnson (195) and Morgan, Langston, and Field (153) found no difference in the C content of fresh and frozen orange juice. Blueberries and strawberries showed no losses in C on freezing, (58, 60). In fact, strawberries could be packed with sugar (frozen-pack) and later made into ice cream with no measurable loss in C.

In this laboratory, Fellers, Young, Isham, and Clague (64) found no loss in freezing asparagus. Fellers and Stepat (62, 63) found that freezing either peas or lima beans in itself caused little loss of C, but the manufacturing operations incidental to shelling, washing, blanching, and freezing often removed 50 percent of this vitamin. However, once frozen, there was but little further change at storage temperatures of -9.4° to -20.2° F. The defrosting of peas, lima beans, and spinach unless quickly done was very destructive to vitamin C. Losses of 70 to over 80 percent were found after defrosting these vegetables for several hours. Obviously, the moral is not to defrost frozen fruits or vegetables until they are ready to be cooked or served raw. By plunging the still-frozen vegetables into boiling water, loss of C is reduced to a minimum.

Effect of Germination and Fermentation on Vitamin C

It is interesting to note that Ghosh and Guha (70) found an 8-fold increase in the C content of mung beans during germination. Germination of potatoes greatly increased the C at first, but this was followed by a marked decrease according to Pett (165). Biswas and Ghosh (11) found the maximum C content in mature peas after soaking 3 days in water. Germination increased the vitamin C 21 to 47 times.

Chang, Ma, Hoo, and Sah (19) examined over 50 Chinese vegetables for C. They found the juices of the lotus and turnip rich in C and possible substitutes for orange juice. It was demonstrated by Yarusova (227) that whereas fresh cucumbers contained 0.08 to .16 unit of C per gram, the salt pickles made from them contained none. Ivanova (97) showed that pumpkin lost one-half the C on pickling. Krauss (115) claimed that apple and some other commercial fruit juices contain little vitamin C. Oxidation destroys the C in stored and fermented cider. Sauerkraut juice is of variable C content as shown by Clow, Marlatt, Peterson, and Martin (22), Lavrov and Yarusova (119), and others. In general, kraut juice and canned kraut are considered only fair sources of C by Parsons and Horn (162), Von Hahn (76), and Clow, Parsons, and Stevenson (24).

Effect of Heat on Vitamin C

A vast amount of research has been carried on relative to the effect of cooking and canning on the C content of foods. Only the more recent studies can be considered here. Attention is again called to the excellent summaries by the British Medical Board (137), Kohman (106), Sherman and Smith (193), the White House Conference Report (12), and others which bring the subject up to about 1931. The use of the rapid titration technic with 2, 6-dichlorophenolindophenol dye (10) has greatly facilitated work in this field. With the Sherman assay method it was difficult to determine under plant conditions the actual effect of the various manufacturing operations on the C content of the food product. The new chemical method makes such studies now relatively simple.

It can be generally assumed that oxidation rather than heat is responsible for losses in vitamin C during the heat treatment of foods. Many experiments of different investigators bear out this statement.

Woods (224), and Richardson, Douglass, and Mayfield (173) found no appreciable loss in baking or boiling potatoes. Results obtained by Thiessen (208) indicated that potatoes boiled at 199° F. for 15 to 18 minutes showed no vitamin C loss. Scheunert (182) found a maximum of 50 percent loss of C in boiling potatoes and as high as 90 to 95 percent loss in cabbage. Scheunert and Wagner (185) demonstrated that potatoes and cabbage were injured less by boiling than by cooking in a pressure cooker. The reverse was true of spinach. According to Yarusova (229) fried potatoes contained only one-half as much vitamin C as boiled potatoes. Von Hahn (77) found that cabbage after cooking retained only 12 to 15 percent of its original vitamin C; cooked horseradish retained 25 percent; and cooked spinach was practically devoid of C. Vinokurov, Eidelman, and Butom (216) found that from 40 to 70 percent of the vitamin C in cabbage passed into the juice on cooking for 30 minutes. Long-continued cooking caused heavy losses in vitamin C. Tressler and Mack (212) reported very little loss in vitamin C as a result of cooking snap beans, peas, or spinach, though considerable of the vitamin passed into the cooking water.

Fresh carrots were cooked without injury to C, but stored carrots showed some loss according to Langley, Richardson, and Andes (117). Under the same conditions the carrots showed decided loss in vitamin C after canning. Hoff (90) showed that canning destroyed 66 percent and cooking 90 percent of the C in spinach. Wasson (218) found that 10 grams of canned spinach did not protect guinea pigs from scurvy, whereas fresh, raw spinach had a daily protective level of 1 to 2 grams. While 10 grams of fresh carrots were protective, 20 grams of canned or cooked carrots were required for protection from scurvy. Remy (172) described experiments showing that canning is at least partly destructive to the C of green beans, spinach, apricots, peas, and strawberries. Barshai, Fomin, and Shvatshko (6) showed that the C in rhubarb stems was not lost in cooking. However, Clague, Fellers, and Stepat (21) found a 30 to 40 percent loss during the process of rhubarb sauce manufacture. They, as well as Hessler and Williams (88), found that canned rhubarb contained much less C than fresh. Newton (160) showed that when turnip greens were boiled for 45 minutes, they retained 14 percent of their C; when boiled for 2 hours, only 6 percent of the C remained. A steam blanch was slightly less destructive to vitamin C than a hot-water blanch. When collards were boiled for 2 hours, 25 percent of the C was lost. This laboratory found that commercial canning destroyed from 50 to 85 percent of the C in peas (62, 63), lima beans, spinach, and green asparagus (64). Whole grain sweet corn was one of the vegetables whose C content was least affected by canning (42). On the other hand, Fellers and Isham (56), MacLeod and Booher (123), and also Eddy, Gurin, and Kohman (46) showed that canning had no effect on the C content of oranges, grapefruit, or their juices. Fermented or candied citron lost all the C but retained the A in experiments reported by Fellers and Smith (61). Blueberries (58, 138) gave variable results as to C retention; some experimental packs showed good retention while others showed poor retention. Retention of C could not be correlated with blanching, kettle cooking, or vacuumization.

Clow and Marlatt (23) found that tomatoes canned by the open-kettle method were slightly inferior to those canned by other methods. They also showed that green tomato pickles retain but little C. Daggs and Eaton (30), and Spohn (200) reported that canned tomatoes and juice were inferior to fresh in C content. Results in this laboratory (54) show that while commercially canned tomato juices are variable in vitaminC content, in general they are good antiscorbutics. Some juices had 6 units per gram while others had only 1 to 2 units per gram. In general, home canned tomato juice was as satisfactory as commerically canned. No significant differences in C content could be observed between homogenized and non-homogenized tomato juices. Kohman, Eddy, and Zall (111), and Kohman, Eddy, and Gurin (110) found some loss in C in the concentration of tomato juice to puree; but the loss was not proportional to the concentration, the tomato concentrate being weight for weight richer in vitamin C than the original tomato. Mathieson (135) found that concentrated tomato pastes with 20 percent total solids contained no more C than paste with 40 percent. Similarly, Aschehoug (1) determined the minimum protective levels for guinea pigs at 8 and 10 grams respectively, for tomato pastes containing 18 and 25 percent total solids. Daniel, Kennedy, and Munsell (31) found definite losses in vitamin C of both tomato and orange juices when prepared 6 hours before use. This loss increased with storage time. Also, Daniel and Rutherford (33) showed that both the canning process and the storage of canned tomatoes and tomato juice had significant destructive effects on vitamin C. The losses varied from 21 to 55 percent. Both factors caused about equal losses of C in canned tomatoes and juice. Losses of vitamin C were greater when storage was carried on in glass containers. Tomato conserve was found to retain only 14 to 15 percent of the original vitamin C of the tomatoes by Soloveichik (199). Giroud, Ratsimamanga, Macheboeuf, Cheftel, and Thuillot (71) showed good retention of vitamin C in canned acid vegetables. According to Hess and Unger (86, 87), and Sherman, La Mer, and Campbell (192), the neutralization of tomato juice destroyed much of its C. Kenny (103) proved that the loss in vitamin C during the heating of tomato juice was correlated with the oxidation potential. Kohman (107) and Kohman, Eddy, and Gurin (110) applied the principle of deaeration and anaerobic handling to the manufacture of tomato juice with good results. Barnby and Eddy (5) found no differences in C content in tomato juice packed in tin or in glass containers. They also found viscolization of the juice to be without effect on its vitamin C activity.

Rigobello (175) pointed out that lemon jelly retained approximately 50 percent of the C value of the lemon. Bacharach, Cook, and Smith (4) showed that citrus marmalade retained only 10 to 30 percent of the C in the fruit. Fellers Isham, and Smith (59) and also Todhunter (210) found that apple sauce lost over 50 percent of the C of the fresh fruit. They found apple pie to be only slightly higher in C content than apple sauce. The former investigators, as well as Bracewell, Hoyle, and Zilva (14), obtained nearly complete retention of C in apples baked in their skins. Becker (9) described Vitapric, a very active vitamin C concentrate made from ripened paprika juice. The content of ascorbic acid is 0.45 percent which is unchanged after sterilization. Miller and Robbins (141) found that guavas lost no C when converted into jelly. Unpublished work in this laboratory showed no C in apple jelly.

Von Euler and Klussmann (51) found that ascorbic acid was much more stable in fruits and in acid solutions than in roots and in green plant tissue. Also, Carteni and Morelli (18) demonstrated much greater losses in C at pH 4.93 than at pH 9.64. Loss of vitamin C by exposure to air is well illustrated by an experiment reported by Kohman, Eddy, and Gurin (108) who showed that shredded carrots lost much C on relatively short exposures. Experience in this laboratory (55) indicates that fresh cider loses its C rather rapidly by oxidation. Prompt refrigeration is necessary to prevent loss. Pasteurization or benzoate preservation have not been effective in conserving the vitamin C in fresh cider, cranberry, blueberry or vegetable juices. Sah, Ma, and Chang (180) found that boiling lotus juice for as little as 5 minutes destroyed over 40 percent of the vitamin C. Morgan, Langston, and Field (153) showed that sodium benzoate could be used in the preservation of orange juice without injuring its C content. That canned foods lose little vitamin C on storage has been shown by Eddy, Kohman, and Halliday (48,) and by Fellers and Isham (56). The latter found that after canning, tomato juice lost no C in 5 months at room temperature.

Summary on Vitamin C

The British Medical Research Council (137) states, "The commercial process of canning vegetables also leads to a considerable degree of destruction of the vitamin C in vegetables like cabbage and runner beans, whereas in tomatoes very little destruction occurs unless there is exposure to air. Actual investigation of products canned commercially has shown that in many cases vitamin C is still present, although a certain amount of loss has usually taken place. This holds for many fruits and vegetables." These recent studies as well as many which have been previously summarized by Kohman (106), Sherman and Smith (193), the British Medical Council (137), and others, show that oxidation is the primary cause of loss of vitamin C in cooked and canned foods. Heat, of course, accelerates oxidation and enzyme activities and is a powerful and not easily controlled element involved in the conservation of C in food manufacturing processes. Blackfan (12) summarizes the subject by the statement, "Vitamin C apparently suffers greater destruction in cooking than in canning due to the greater exposure of oxygen in the former process. The losses reported for cooked vegetables are probably unnecessarily large because of the long cooking periods used. Experiments are needed to determine the vitamin C content of vegetables cooked only until they are tender. In cooking and canning, the water soluble substances find their way into the surrounding liquid. Vitamin C is stabilized by acid and therefore suffers less destruction in canning fruits and acid vegetables." Scheunert's (183) conclusions, based on German experiments, agree with those just cited from England and America.

GENERAL SUMMARY

The effects of storage, freezing, drying, and thermal treatments on the several vitamins are discussed at the end of the respective chapters. A bibliography of 235 references to the literature is appended.

Generally speaking, ordinary storage and to a lesser extent cold storage in air have no serious effect on vitamins D, E, and G; have a slight to moderate destructive action on vitamins A and B; and cause serious loss of vitamin C, particularly when storage is long continued. Losses are reduced when storage is near the freezing point. Shipped-in vegetables may lose substantial quantities of vitamin C during shipment and incidental marketing operations. This is not true in the case of most fruits and such acid vegetables as tomatoes and rhubarb. Properly packaged frozen fruits and vegetables show practically no losses in any of the vitamins even after long storage at 0° F. or below.

Destruction of vitamin C is very rapid when frozen fruits and vegetables are defrosted in air.

Little loss in vitamin C occurs if solidly frozen vegetables are cooked in boiling water without previous defrosting.

Sun-drying is more destructive to vitamins A and C than artificial dehydration.

Fermentation of fruits and vegetables is injurious to vitamin C.

In general, heat treatments such as cooking and canning are not injurious to any of the vitamins, but the accompanying oxidations and other destructive reactions, unless carefully controlled, are decidedly injurious to vitamins B and C. Fruits or vegetables containing added acid may be heated with less destruction to vitamins B, C, and G than non-acid foods. Thus, canned fruits retain vitamin C very well, while canned vegetables lose much of their original C. Modern methods of vacuumization and air removal and sealed packaging now used in the food preservation industries are practical aids in preventing vitamin losses through oxidation. It is not believed that cooking and canning are harmful to the vitamins A, G, D, and E of fruits, vegetables and cereals.

Heat in the presence of alkalies is very destructive to all the vitamins.

Rapid cooking, with minimum exposure to air, serves to minimize losses of vitamins C, A, and B.

Food manufacturing operations such as blanching, open-kettle cooking, pulping, and filling containers are ordinarily destructive to vitamin C and probably to a lesser degree to B and A as well.

There is no satisfactory evidence that foods once canned lose appreciable quantities of any vitamins on storage. Losses of vitamins C and A in reheating canned foods for table use are small.

Large quantities of the water-soluble vitamins B, C, and G are dissolved in the cooking water of fruits and vegetables and are lost unless this cooking water is utilized.

In conclusion, it should be borne in mind that this field of research is in an active state of change. The literature is being multiplied very rapidly. There is still need for much more research before all the effects of environmental factors on vitamin stability can be stated with finality.

LITERATURE CITED

(1) Aschehoug, V., *Tids. Hermetikind.* 19: 217–221 (1933).
(2) Bacharach, A. L., *Chem. and Ind.* 1933: 68–71 (1933).
(3) Bacharach, A. L., *Food* 4: 44–45 (1934).
(4) Bacharach, A. L., Cook, P. M., and Smith, E. L., *Biochem. J.* 28: 1038–1047 (1934).
(5) Barnby, H. A., and Eddy, W. H., *Glass Packer* 11: 33–34 (1932).
(6) Barshai, T. E., Fomin, S. V., and Shvatshko, D. K., *Ukrain. Biochem. J.* 7: No. 1: 125–131 (1934).
(7) Batchelder, E. L., *J. Nutrition* 7: 647–655 (1934).
(8) Batchelder, E. L., Miller, K., Sevals, N., and Starling. L., *J. Am. Dietetic Assoc.* 11: 115–118 (1935).
(9) Becker, E., *Z. Vitaminforsch.* 4: 255–259 (1935).
(10) Bessey, O. A., and King, C. G., *J. Biol. Chem.* 103: 687–698 (1933).
(11) Biswas, H. G., and Ghosh, A. R., *Science and Culture* 1: 778–779 (1936).
(12) Blackfan, K. D., Chairman Committee on Growth and Development of the Child. III. Nutrition. White House Conference on Child Health Protection. Century Co., N. Y., 532 pp. (1932).
(13) Bogoliubova, O. M., *Arch. Sci. Biol. (U.S.S.R.)* 31: 322–329 (1931).
(14) Bracewell, M. F., Hoyle, E., and Zilva, S. S., *Biochem. J.* 24: 82–90 (1930).
(15) Bracewell, M. F., Kidd, F., West, C., and Zilva, S. S., *Biochem. J.* 25: 138–143 (1931).
(16) Bracewell, M. F., and Zilva, S. S., *Biochem. J.* 25: 1081–1089 (1931.)
(17) Campbell, M. E. D., and Chick, H., *Lancet* II: 320–332 (1919).
(18) Carteni, A., and Morelli, A., *Boll. Soc. Ital. Biol. Sper.*, 11: 158–160 (1936).
(19) Chang, H. C., Ma, T. S., Hoo, V., and Sah, P. P. T., *J. Chinese Chem. Soc.* 2: 184–191 (1934).
(20) Chick, H., and Copping, A. M., *Biochem. J.* 24: 932–938 (1930).
(21) Clague, J. A., Fellers, C. R., and Stepat, W., *Am. Soc. Hort. Sci. Proc.* 33: 624–626 (1936).
(22) Clow, B., Marlatt, A. L., Peterson, W. A., and Martin, E. A., *J. Agr. Research* 39: 963–971 (1929).
(23) Clow, B., and Marlatt, A. L., *J. Agr. Research* 40: 767–775 (1930).
(24) Clow, B., Parsons, H. T., and Stevenson, I., *J. Agr. Research* 41: 51–64 (1930).
(25) Coffin, J., *J. Am. Dietetic Assoc.* 11: 119–127 (1935).
(26) Coward, K. H., and Morgan, B., *Brit. Med. J. Part* II: 1041–1044 (1935).
(27) Cowell, S. J., *Bul. Hyg.* 11: 255–268 (1936).
(28) Crist, J. W., and Dye, M., *J. Biol. Chem.* 81: 525–532 (1929).
(29) Cultrera, R., *Ind. Ital. Conserve Aliment.* 9: 1–8 (1934).
(30) Daggs, R. G., and Eaton, A. G., *Ind. and Eng. Chem.* 26: 292–295 (1934).
(31) Daniel, E. P., Kennedy, M. H., and Munsell, H. E., *J. Home Econ.* 28: 470–474 (1936).
(32) Daniel, E. P., and Munsell, H. E., *J. Agr. Research* 44: 59–70 (1932).
(33) Daniel, E. P., and Rutherford, M. B., *Food Research* 1: 341–347 (1936).
(34) Daniels, A. L., Giddings, M. L., and Jordan, D., *J. Nutrition* 1: 455–466 (1929).
(35) Day, P. L., *Southern Med. J.* 24: 876 (1931).
(36) Day, P. L., and Darby, W. G., *J. Home Econ.* 25: 319–323 (1933).
(37) Delf, E. M., *Biochem. J.* 12: 416–447 (1918).
(38) Delf, E. M., and Skelton, R. F., *Biochem. J.* 12: 448–463 (1918).
(39) Douglass, R., Halloway, M., Williams, J. C., and Garrison, A., *J. Nutrition* 7: 27–40 (1934).
(40) Douglass, D., and Richardson, J. E., *J. Home Econ.* 22: 859–860 (1930).
(41) Drummond, J. C., Coward, K. H., and Watson, A. F., *Biochem. J.* 15: 540–552 (1921).
(42) Dunker, C. F., Fellers, C. R., and Fitzgerald, G. A., *Food Research* 2: (in press) (1937).
(43) Dutcher, R. A., *Pa. Agr. Expt. Sta. Bul.* 275, 24 pp. (1932).
(44) Dutcher, R. A., and Francis, E., *J. Dairy Sci.* 9: 379–387 (1926).
(45) Dutcher, R. A., and Outhouse, J., *Proc. Soc. Expt. Biol. and Med.* 20: 450 (1923).
(46) Eddy, W. H., Gurin, C. Z., and Kohman, E. F., *Ind. and Eng. Chem.* 24: 457–460 (1932).
(47) Eddy, W. H., Kohman, E. F., and Carlsson, V., *Ind. and Eng. Chem.* 17: 69–74 (1925).

(48) Eddy, W. H., Kohman, E. F., and Halliday, N., *Ind. and Eng. Chem.* 21: 347 (1929).

(49) Elvehjem, C. A., Sherman, W. C., and Arnold, A., *J. Biol. Chem.* 109: Proc. XXIX, p. XXIX (1935).

(50) Euler, H. von, *Annual Review Biochem.* 5: 355–378 (1936).

(51) Euler, H. von, and Klussmann, E., *Z. Physiol. Chem.* 219: 215–223 (1933).

(52) Fellers, C. R., *Am. J. Pub. Health* 22: 601–611 (1932).

(53) Fellers, C. R., *Am. J. Pub. Health* 25: 1340–1345 (1935).

(54) Fellers, C. R., Clague, J. A., and Isham, P. D., *J. Home Econ.* 27: 447–451 (1935).

(55) Fellers, C. R., Cleveland, M. M., and Clague, J. A., *J. Agr. Research* 46: 1039–1045 (1933).

(56) Fellers, C. R., and Isham, P. D., *J. Home Econ.* 24: 827–832 (1932).

(57) Fellers, C. R., and Isham, P. D., *Mass. Agr. Expt. Sta. Bul.* 296, 19 p. (1933).

(58) Fellers, C. R., and Isham, P. D., *J. Agr. Research* 47: 163–165 (1933).

(59) Fellers, C. R., Isham, P. D., and Smith, G. G., *Am. Soc. Hort. Sci. Proc.* 29: 93–97 (1932).

(60) Fellers, C. R., and Mack, M. J., *Ind. and Eng. Chem.* 25: 1051–1052 (1933).

(61) Fellers, C. R., and Smith, E. G., *J. Agr. Research* 53: 859–867 (1936).

(62) Fellers, C. R., and Stepat, W., *Am. Soc. Hort. Sci. Proc.* 33: 627–633 (1936).

(63) Fellers, C. R., Stepat, W., and Fitzgerald, G. A., *J. Bact.* 32: 359–360 (1936).

(64) Fellers, C. R., Young, R. E., Isham, P. D., and Clague, J. A., *Am. Soc. Hort. Sci. Proc.* 31: 145–151 (1934).

(65) Fomin, S. V., and Makarova, P. T., *Ukrain. Biochem. J.* 8 (1): 191–202 (1935).

(66) Fraps, G. S., and Treichler, R., *Tex. Agr. Expt. Sta. Bul.* 447, 34 p. (1933).

(67) Fraps, G. S., and Treichler, R., *Ind. and Eng. Chem.* 25: 465–466 (1933).

(68) Fraps, G. S., and Treichler, R., *J. Agr. Research* 47: 539–541 (1933).

(69) Gerstenberger, H. J., Smith, D. M., and Hacker, G. L., *J. Pediat.* 3: 93 (1933).

(70) Ghosh, A. R., and Guha, B. C., *J. Indian Chem. Soc.* 12: 30–36 (1935).

(71) Giroud, A., Ratsimamanga, A. R., Macheboeuf, M. A., Cheftel, H., and Thuillot, M. L., *Bul. Soc. Sci. Hyg. Aliment.* 24: 228–239 (1936).

(72) Goldberger, J., and Wheeler, G. A., *U. S. Pub. Health Repts.* 44: 2769–2771 (1929).

(73) Gould, S., Tressler, D. K., and King, C. G., *Food Research* 1: 427–434 (1936).

(74) Guerrant, N. B., Dutcher, R. A., Tabor, F. S., and Rasmussen, R., *J. Nutrition* 11:383–390 (1936).

(75) Guha, B. C., and Chakravorty, P. N., *Indian J. Med. Research* 21: 211–219 (1933).

(76) Hahn, F. V. von, *Z. Untersuch. Lebensm.* 59: 4–18 (1930).

(77) Hahn, F. V. von, *Z. Volksernahrung Diatkost* 6: 337–341, 364–366, 372–373 (1931); 7: 5–6 (1932).

(78) Halliday, N., Nunn, M. J., and Fisher, J. D., *J. Biol. Chem.* 95: 371–385 (1932).

(79) Hanning, F., *J. Am. Dietetic Assoc.* 12: 231–236 (1936).

(80) Hanning, F., *J. Nutrition* 8: 449–456 (1934).

(81) Hanning, F., *J. Am. Dietetic Assoc.* 9: 295–305 (1933).

(82) Harris, L. J., *Annual Review Biochem.* 4: 331–382 (1935).

(83) Hassan, A., and Basili, R., *Biochem. J.* 26: 1846–1850 (1932).

(84) Hauge, S. M., and Aitkenhead, W., *J. Biol. Chem.* 93: 657–665 (1931).

(85) Hermano, A. J., and Aguila, P. J., *Phillipine J. Sci.* 58: 425–433 (1935).

(86) Hess, A. F., and Unger, J. L., *Proc. Soc. Expt. Biol. and Med.* 17: 49–50 (1919).

(87) Hess, A. F., and Unger, J. L., *Proc. Soc. Expt. Biol. and Med.* 18: 143 (1921).

(88) Hessler, M. C., and Williams, Z., *Mo. Agr. Expt. Sta. Bul.* 272, 68 p. (1929).

(89) Hodgson, R. E., and Knott, J. C., *J. Agr. Research* 48: 439–446 (1934).

(90) Hoff, J. J., *Z. Ernahr.* 3: 355–359 (1933).

(91) House, M. C., Nelson, P. M., and Haber, E. S., *J. Biol. Chem.* 81: 495–504 (1929).

(92) House, M. C., Nelson, P. M., and Haber, E. S., *Iowa Agr. Expt. Sta. Research Bul.* 120 (1930); *Expt. Sta. Record* 63: 93 (1930).

(93) Hume, E. M., *Biochem. J.* 15: 30–48 (1921).

(94) Hunt, C. H., Record, P. R., and Bethke, R. M., *J. Agr. Research* 51: 251–258 (1935).

(95) Hunt, C. H., Record, P. R., Wilder, W., and Bethke, R. M., *Ohio Agr. Expt. Sta. Bimonthly Bul.* 18: 104–106 (1933).

(96) Ivanov, N. N., Bukin, V. N., Borokhovich, B. O., and Povolotzkaya, K. L., *Bul. Applied Botany, Genetics, Plant Breeding (U.S.S.R.)* Series A, No. 8: 95–111 (1933).

(97) Ivanova, A., *Voprosui Pitaniya* 2, No. 5: 31–34 (1933).

(98) Izumrudova, T. L., *Z. Untersuch. Lebensm.* 71: 324–326 (1936).

(99) Jancik, V., *Master's Dissertation, Mass. State College* 48 pp. (1936). *Food Research* 2: in press. 1937.

(100) Jones, D. B., and Nelson, E. M., *Am. J. Pub. Health* 20: 387–394 (1930).

(101) Karrer, P., and Wehrli, H., *Nova Acta Leopoldina* N. S. 1: 175–275 (1933).

(102) Keenan, J. A., and Kline, O. L., *J. Biol. Chem.* 105: Proc. XXVIII, p. XLV (1934).

(103) Kenny, C. L., *Dissertation. Columbia Univ., New York* (1926).

(104) Kline, O. L., Keenan, J. A., Elvehjem, C. A., and Hart, E. B., *Wis. Agr. Expt. Sta. Bul.* 430 (Ann. Rept. 1933–34): 138–140 (1935).

(105) Koch, E. M., and Koch, F. C., *Ind. and Eng. Chem.* 24: 351–352 (1932).

(106) Kohman, E. F., *Nat. Canners Assoc., Research Lab., Bul. 19-L* Revised. 117 pp. (1929).

(107) Kohman, E. F., *Glass Packer* 4: 276–277 (1931).

(108) Kohman, E. F., Eddy, W. H., and Gurin, C. Z., *Ind. and Eng. Chem.* 23: 808–811 (1931).

(109) Kohman, E. F., Eddy, W. H., and Gurin, C. Z., *Ind. and Eng. Chem.* 23: 1064–1066 (1931).

(110) Kohman, E. F., Eddy, W. H., and Gurin, C. Z., *Ind. and Eng. Chem.* 25: 682–684 (1933).

(111) Kohman, E. F., Eddy, W. H., and Zall, C., *Ind. and Eng. Chem.* 22: 1015–1017 (1930).

(112) Kohman, E. F., Sanborn, N. H., Eddy, W. H., and Gurin, C. Z., *Ind. and Eng. Chem.* 26: 758–761 (1934); 27: 235–236 (1935).

(113) Kramer, M. M., and Agan, A. T., *J. Home Econ.* 26: 638–639 (1934).

(114) Kramer, M. M., *Kan. Agr. Expt. Sta. Biennial Rept. of the Director* 6 (1930–1932): 113–114 (1932).

(115) Krauss, G., *Z. Untersuch. Lebensm.* 68: 377–389 (1934).

(116) Krizenecky, J., and Nevalonnyj, M., *Z. Untersuch. Lebensm.* 66: 278–288 (1933).

(117) Langley, D. D., Richardson, J. E., and Andes, E. J., *Mont. Agr. Expt. Sta. Bul.* 276: 3–32 (1933).

(118) Lavrov, B. A., Yanovskaya, B. I., and Yarusova, N., *Z. Untersuch. Lebensm.* 63: 498–501 (1932).

(119) Lavrov, B. A., and Yarusova, N., *Biochem. Z.* 229: 115–127 (1930).

(120) Leersum, E. C. van, and Hoogenboom, N. P., *Nederland. Tijdschr. Geneesk.* 74, II: 5127–5133 (1930).

(121) Lo, T. Y., *Nutrition Bul. Natl. Peiping Univ., Coll. Agr.* (B) 1: 13–26 (1935).

(122) Lo, T. Y., *Nutrition Bul. Natl. Peiping Univ., Coll. Agr.* 2: 34–42 (1935).

(123) MacLeod, G., and Booher, L., *J. Home Econ.* 22: 588–593 (1930).

(124) McCay, C. M., *Ind. and Eng. Chem.* 27: 235 (1935).

(125) McCollum, E. V., *Annual Review Biochem.* 5: 379–402 (1936).

(126) McKittrick, E. J., and Thiessen, E. J., *Wyo. Agr. Expt. Sta. Ann. Rept.* 42 (1931–32): 25–26 (1932).

(127) Maclinn, W. A., Fellers, C. R., and Buck, R. E., *Am. Soc. Hort. Sci. Proc.* 1936: (In press) (1937).

(128) Mack, G. L., Tressler, D. K., and King, C. G., *Food Research* 1: 231–235 (1936).

(129) Mack, M. J., Fellers, C. R., Maclinn, W. A., and Bean, D. A., *Food Research* 1: 223–230 (1936).

(130) Manville, I. A., and Chuinard, F. G., *J. Am. Dietetic Assoc.* 8: 504–516 (1933).

(131) Manville, I. A., and Chuinard, F. G., *J. Am. Dietetic Assoc.* 10: 217–227 (1934).

(132) Manville, I. A., McMinis, A. S. and Chuinard, F. G., *J. Am. Dietetic Assoc.* 10: 135–152 (1934).

(133) Manville, I. A., McMinis, A. S., and Chuinard, F. G., *Food Research* 1: 121–140 (1936).

(134) Margaillan, L. *Compt. Rend. Acad. Sci. France* 191: 725–727 (1930).

(135) Mathieson, E., *Tids. Hermetikind.* 21: 61–64 (1935).

(136) Matzko, S. N., *Z. Untersuch. Lebensm.* 70: 279–284 (1935).

(137) Medical Research Council, Vitamins: A Survey of Present Knowledge, Spec. Rept. Series No. 167, London, 332 pp. (1932).

(138) Merriam, O., and Fellers, C. R., *Food Research* 1: 501-512 (1936).

(139) Miller, C. D., *J. Home Econ.* 16: 18–26, 74–79 (1924).

(140) Miller, C. D., and Robbins, R. C., *Hawaii Agr. Expt. Sta. Ann. Rept.* 1932: 18–19 (1933).

(141) Miller, C. D., and Robbins, R. C., *Hawaii Agr. Expt. Sta. Ann. Rept.* 1934: 29–30 (1935).

(142) Mitchell, H. S., *J. Am. Dietetic Assoc.* 5: 28–31 (1929).

(143) Miura, M., and Tsujimura, M., *Sci. Papers Inst. Phys. Chem. Research (Tokyo)* 20: 129–144 (1933).

(144) Moore, M. C., and Moseley, H. W., *Science* 78: 368–369 (1933).

(145) Morgan, A. F., *J. Home Econ.* 25: 603–611 (1933).

(146) Morgan, A. F., *Am. J. Pub. Health* 25: 328–335 (1935).

(147) Morgan, A. F., and Field, A., *J. Biol. Chem.* 88: 9–25 (1930).

(148) Morgan, A. F., Field, A., and Nichols, P. F., *J. Agr. Research* 42: 35–45 (1931).

(149) Morgan, A. F., Field, A., Kimmel, L., and Nichols, P. F., *J. Nutrition* 9: 383–394 (1935).

(150) Morgan, A. F., and Francis, L. D., *Am. J. Physiol.* 69: 67–77 (1924).

(151) Morgan, A. F., Hunt, M. J., and Squier, M., *J. Nutrition* 9: 395–402 (1935).

(152) Morgan, A. F., Kimmel, L., Field, A., and Nichols, P. F., *J. Nutrition* 9: 369–382 (1935).

(153) Morgan, A. F., Langston, C. I., and Field, A., *Ind. and Eng. Chem.* 25: 1174–1176 (1933)

(154) Morgan, A. F., and Smith, L. L. W., *Proc. Soc. Expt. Biol. and Med.* 26: 44–47 (1928).

(155) Munsell, H. E., *J. Home Econ.* 28: 320–328 (1936).

(156) Munsell, H. E., and Kennedy, M. H., *J. Agr. Research* 51: 1041–1046 (1935).

(157) Munsell, H. E., and Kifer, H. B., *J. Home Econ.* 24: 823–826 (1932).

(158) Murri, I. K., Onokhova, N. P., Kudryavtzeva, A. V., and Gutzevich, G. K., *Bul. Applied Botany, Genetics, Plant Breeding (U.S.S.R.)* Suppl. 67: 113–127 (1934).

(159) Nelson, P. M., Swanson, P. P., and Haber, E. S., *Iowa Agr. Expt. Sta. Rept. on Agr. Research* 1932–1933: 118 (1933). 1933–1934: 146–147 (1934).

(160) Newton, C. L., *Ga. Agr. Expt. Sta. Bul.* 167: 3–20 (1931).

(161) Norris, R. J., *Bul. Basic Science Research* 3: 89–100 (1931).

(162) Parsons, H. T., and Horn, C., *J. Agr. Research* 47: 627–638 (1933).

(163) Parsons, H. T., Stevenson, I., Mullen, I., and Horn, C., *J. Home Econ.* 23: 366–372 (1931).

(164) Pelc, H., and Podzimková, M., *Trav. Inst. Hyg. Pub. Tchécoslov.* 3, No. 3: 57–78 (1932): *Expt. Sta. Record* 72: 569, (1935).

(165) Pett, L. B., *Biochem. J.* 30: 1228–1232 (1936).

(166) Pochino, M., *Pediat. Med. Prat.* 10: 16 (1935).

(167) Poe, C. F., and Gambill, E. L., *J. Nutrition* 9: 119–122 (1935).

(168) Priestly, H., *Chem. Eng. Mining Rev.* 25: 377–380 (1933).

(169) Quinn, E. J., Hartley, J. G., and Derow, M. A., *J. Biol. Chem.* 89: 657–663 (1930).

(170) Ranganathan, S., *Indian J. Med. Research* 23: 239–252 (1935).

(171) Ranganathan, S., *Indian J. Med. Research* 23: 755–762 (1935).

(172) Remy, E., *Arch. Hyg.* 107: 139–154 (1932).

(173) Richardson, J. E., Douglass, D., and Mayfield, H., *Potato Assoc. Am. Proc.* 16: 69–73 (1929–30); *Expt. Sta. Record* 64: 395 (1931).

(174) Richardson, J. E., and Mayfield, H., *Science* 76: 498–500 (1932).

(175) Rigobello, G., *Boll. Soc. Ital. Biol. Sper.* 7: 736–740 (1932).

(176) Roehm, G. H., *J. Home Econ.* 27: 663–666 (1935).

(177) Rojahn, C. A., and Wirth, E., *Apoth. Ztg.* 47: 838–841 (1932).

(178) Russell, W. C., Taylor, M. W., and Chichester, D. F., *N. J. Agr. Expt. Sta. Bul.* 560: 1–8 (1934).

(179) Rygh, O., *Nature* 133: 255 (1934).

(180) Sah, P. P. T., Ma, T. S., and Chang, H. C., *J. Chinese Chem. Soc.* 2: 260–265 (1934).

(181) Sah, P. P. T., Ma, T. S., and Hoo, V., *J. Chinese Chem. Soc.* 2: 175–178 (1934).

(182) Scheunert, A., *Volksernahrung* 4: 18–22 (1929); *Chem. Zentr.* I: 1476 (1929).

(183) Scheunert, A., Der Vitamingehalt der Deutschen Nahrungsmittel, Berlin, 40 pp. (1930). J. Springer.

(184) Scheunert, A., and Reschke, J., *Deut. Med. Wochschr.* 57: 349–351 (1931).

(185) Scheunert, A., and Wagner, E., *Hauswirtschaft in Wiss. Praxis* 2: 4 (1929). *Chem. Zentr.* II: 2195 (1930).

(186) Scheunert, A., and Wagner, E., *Biochem. Z.* 236: 29–34 (1931).

(187) Sebrell, W. H., *U. S. Pub. Health Repts.* 49: 754–756 (1934).

(188) Sebrell, W. H., Wheeler, G. A., and Hunt, D. J., *U. S. Pub. Health Repts.* 50: 1333–1341 (1935).

(189) Shelesnii, G. P., and Kanevska, E. S., *Voprosui Pitaniya* 2: No. 4: 21–23 (1933).

(190) Shepilevska, N. E., and Izumrudova, T. L., *Z. Untersuch. Lebensm.* 70: 274–276 (1935).

(191) Sherman, H. C., and Burton, G. W., *J. Biol. Chem.* 70: 639–645 (1926).

(192) Sherman, H. C., La Mer, V. K., and Campbell, H. L., *Proc. Natl. Acad. Sci.* 7: 279–281 (1921).

(193) Sherman, H. C., and Smith, S. L., The Vitamins, Chemical Catalog Co., New York, 575 pp. (1931).

(194) Sherman, H. C., and Spohn, A., *J. Am. Chem. Soc.* 45: 2719–2728 (1923).

(195) Shrader, J. H., and Johnson, A. H., *Ind. and Eng. Chem.* 26: 869–874 (1934).

(196) Smith, S. L., *U. S. Dept. Agr. Circ.* 84, 55 pp. (1929).

(197) Smith, G. G., and Fellers, C. R., *Am. Soc. Hort. Sci. Proc.* 31: 89–95 (1934).

(198) Smith, M. C., and Meeker, L. A., *Ariz. Agr. Expt. Sta. Tech. Bul.* 34: 305–317 (1931).

(199) Soloveichik, I. Y., *Voprosui Pitaniya* 4: No. 5: 137–140 (1935).

(200) Spohn, A., *J. Agr. Research* 43: 1109–1113 (1931).

(201) Spruyt, J. P., and Donath, W. F., *Mededeel. Dienst Volksgezondheid Nederland. — Indie* 21: 64–70 (1932).

(202) Steenbock, H., and Boutwell, P. W., *J. Biol. Chem.* 41: 163–171 (1920).

(203) Steenbock, H., and Gross, E. G., *J. Biol. Chem.* 40: 501–532 (1919).

(204) Steenbock, H., and Gross, E. G., *J. Biol. Chem.* 41: 149–162 (1920).

(205) Steenbock, H., Scott, H. T., and Irwin, M. H., *Wis. Agr. Expt. Sta. Bul.* 428, (*Ann. Rept.* 1932–3): 28 (1934).

(206) Steenbock, H., and Sell, M. T., *J. Biol. Chem.* 51: 63–76 (1922).

(207) Swanson, P. P., Nelson, P. M., and Haber, E. S., *Iowa Agr. Expt. Sta. Ann. Rept.* 1930–31: 91–92 (1931).

(208) Thiessen, E. J., *Wyo. Agr. Expt. Sta. Bul.* 213: 3–22 (1936).

(209) Tillmans, J., Hirsch, P., and Hirsch, W., *Z. Untersuch. Lebensm.* 63: 1–20 (1932).

(210) Todhunter, E. N., *Proc.* 31st *Ann. Meeting Wash. State Hort. Soc.* 43–46 (1935).

(211) Todhunter, E. N., *Food Research* 1 (5): 435–443 (1936).

(212) Tressler, D. K., and Mack, G. L., *Am. J. Pub. Health* 26: 905–909 (1936).

(213) Tressler, D. K., Mack, G. L., and King, C. G., *Food Research* 1: 3–7 (1936).

(214) Vacca, C., *Quaderni Nutrizione* 1: 424–432 (1934–35).

(215) Veen, A., G., van, *Geneesk. Tijdschr. Nederland. — Indie* 73: 945–957 (1933).

(216) Vinokurov, S. G., Eidelman, M. M., and Butom, M. L., *Kharkov State Med. Inst. Jubilee J.* 1935: 142–161 (1935).

(217) Waltner, K., *Z. Vitaminforsch.* 3: 245–247 (1934).

(218) Wasson, G. E., *S. Dak. Agr. Expt. Sta. Bul.* 261: 3–28 (1931).

(219) Weatherby, L., *Calif. Avocado Assoc. Yearbook* 100–105 (1930): *Expt. Sta. Record* 64: 587 (1930).

(220) Wheeler, G. A., *U. S. Pub. Health Repts.* 46: 2663–2668 (1931).

(221) Wheeler, G. A., *U. S. Pub. Health Repts.* 48: 67–77 (1933).

(222) Whipple, D., *J. Nutrition* 9: 163–173 (1935).

(223) Witt, N. F., and Poe, E. E., *Fruit Products J.* 15: 274–275, 283 (1936).

(224) Woods, E., *Ida. Agr. Expt. Sta. Bul.* 219: 3–29 (1935).

(225) Woods, E., Atkeson, F. W., Wellhousen, H., and Johnson, R. F., *J. Dairy Sci.* 19: 581–596 (1936).

(226) Yanovskaya, B. I., *Voprosui Pitaniya* 4, No. 2: 51–54 (1935).

(227) Yarusova, N. S., *Z. Untersuch. Lebensm.* 68: 391–394; 395–403 (1934).

(228) Yarusova, N. S., *Voprosui Pitaniya* 4, No. 5: 125–129 (1935).

(229) Yarusova, N. S., *Voprosui Pitaniya* 4, No. 6: 128–130 (1935).

(230) Yarusova, N. S., and Mikhailina, M., *Voprosui Pitaniva* 5, No. 3: 38–40 (1936).

(231) Yarusova, N. S., and Savel'eva, A. A., *Voprosui Pitaniya* 5, No. 3: 35–37 (1936).

(232) Yarusova, N. S., and Yanovska, B., *Z. Untersuch. Lebensm.* 68: 394–395 (1934).

(233) Zilva, S. S., Kidd, F., and West, C., *Dept. Sci. and Ind. Research*, (*Brit.*) *Rept. Food Investigation Board* 1930: 65–66 (1931).

(234) Zilva, S. S., Kidd, F., and West, C., *Dept. Sci. and Ind. Research*, (*Brit.*) *Rept. Food Investigation Board* 1932: 89–90 (1933).

(235) Zilva, S. S., Kidd, F., and West, C., *Dept. Sci. and Ind. Research*, (*Brit.*) *Rept. Food Investigation Board* 1933: 80 (1934).

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINSTRATION AND FINANCE
4m. 3–'37. No. 41.

140
339

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 339 MARCH 1937

VIRGINIA AGRICULTURAL EXPE

Annual Report

For the Fiscal Year Ending November 30, 1936

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Trustee Committee on Experiment Station

	Term Expires
BUTTERICK, DAVID H., Arlington, *Chairman*	1939
LEACH, MRS. LOTTIE A., Walpole	1937
FROST, HAROLD L., Arlington	1938
MALCOLM, DAVID J., Charlemont	1939
WHITMORE, PHILIP F., Sunderland	1941
CHANDLER, JOHN, Sterling Junction	1942

Experiment Station Staff, December, 1936

HUGH P. BAKER, President of the College

SIEVERS, FRED J., Director
GASKILL, EDWIN F., Assistant to the Director
O'DONNELL, MARGARET H., Technical Assistant

KENNEY, FRED C., Treasurer
FELTON, F. ETHEL, Editor
CHURCH, LUCIA G., Secretary

Archibald, John G., Animal Husbandry
§Bergman, Herbert F., Cranberries
*Bourne, Arthur I., Entomology
*Bradley, Leon A., Bacteriology
*Cance, Alexander E., Economics
*Chenoweth, Walter W., Horticultural Manufactures
Colby, William G., Agronomy
Doran, William L., Botany
*Eisenmenger, Walter S., Agronomy
Fellers, Carl R., Horticultural Manufactures
*Frandsen, Julius H., Dairy Industry
†*Franklin, Henry J., Cranberries
Freeman, Monroe E., Chemistry
Fuller, James E., Bacteriology
*Gaskill, Edwin F., Station Service
Gibbs, Charles S., Veterinary Science
*Graham, John C., Poultry Husbandry
‡Guba, Emil F., Botany
*Gunness, Christian I., Agricultural Engineering
*Haskins, Henri D., Fertilizer Law
Hays, Frank A., Poultry Husbandry
Holland, Edward B., Chemistry
§Kightlinger, Clifford V., Tobacco-Disease Investigations
‡*Koon, Ray M., Horticulture
*Lentz, John B., Veterinary Science
*Lindsey, Adrian H., Agricultural Economics and Farm Management
Lindsey, Joseph B., Chemistry (Professor Emeritus)
*Mitchell, Helen S., Home Economics
Morse, Fred W., Chemistry (Professor Emeritus)
*Osmun, A. Vincent, Botany
*Rice, Victor A., Animal Husbandry
*Ritchie, Walter S., Chemistry
Rozman, David, Economics
Shaw, Jacob K., Pomology
*Smith, Philip H., Feed, Dairy and Seed Laws
*Snyder, Grant B., Olericulture
*Thayer, Clark L., Floriculture
*Van Meter, Ralph A., Pomology
Van Roekel, Henry, Veterinary Science
‡Whitcomb, Warren D., Entomology
*Wood, Basil B., Library

Bailey, John S., Pomology
Bennett, Emmett, Chemistry
Brown, Alfred A., Agricultural Economics and Farm Management
Bullis, Kenneth L., Veterinary Science
Creek, Charles R., Agricultural Economics and Farm Management
‡Dempsey, Paul W., Horticulture

DeRose, H. Robert, Fertilizer Law
Flint, Oliver S., Veterinary Science
France, Ralph L., Bacteriology
‡Graves, George, Horticulture
Jones, Carleton P., Chemistry
Jones, Linus H., Botany
McKenzie, Malcolm A., Botany
McLaughlin, Frederick A., Seed Law
Mueller, William S., Dairy Industry
‡White, Harold E., Floriculture
‡Young, Robert E., Olericulture

Allen, Harry L., Feed, Fertilizer and Dairy Laws
Ball, Alyn S., Botany
Becker, William B., Entomology
‡Bemben, Michael, Olericulture
Caughey, Robert A., Chemistry
Clague, John A., Horticultural Manufactures
Clarke, Miriam K., Veterinary Science
Congdon, George S., Bacteriology
Cook, Gladys M., Home Economics
Crosby, Earl, Veterinary Science
Donley, J. Elizabeth, Agricultural Economics and Farm Management
‡Donnelly, Edward B., Floriculture
Esselen, William B., Jr., Station Service
‡Garland, William, Entomology
‡Gilgut, Constantine J., Botany
Glickstein, Myer, Dairy Industry
Goldfaden, Mildred, Home Economics
Hoefle, Olive M., Seed Law
Howard, James T., Feed, Fertilizer and Dairy Laws
Hughes, Mary C., Pomology
Jewett, Felicia, Veterinary Science
†Kelley, Joseph L., Cranberries
Kucinski, Karol, Agronomy
Kuzmeski, John W., Fertilizer Law
Levine, Arthur S., Horticultural Manufactures
Merriam, Oreana A., Home Economics
Miner, Gladys I., Botany
Parkinson, Leonard R., Station Service
Plastridge, Daniel C., Agricultural Economics and Farm Management
Sanborn, Ruby, Poultry Husbandry
Sherburne, Ruth E., Economics
Smith, Chester W., Agricultural Economics and Farm Management
Southwick, Larwence, Pomology
Spear, Arthur J., Station Service
Spelman, Albert F., Feed Law
‡Tiffany, Harold S., Horticulture
§Truran, Walton E., Cranberries
‡Wilson, Harold A., Olericulture
Yegian, Hrant M., Agronomy

*In Charge †At East Wareham ‡At Waltham §With U.S.D.A

CONTENTS

PAGE

Introduction 4

Department Reports:

Agricultural Economics and Farm Management 6
Agricultural Engineering 8
Agronomy 8
Animal Husbandry 18
Bacteriology 23
Botany 25
Chemistry 32
The Cranberry Station 36
Dairy Industry 41
Economics 45
Entomology 46
Feed Control Service 61
Fertilizer Control Service 63
Floriculture 64
Home Economics 67
Horticultural Manufactures 69
Horticulture 73
Olericulture 74
Pomology 77
Poultry Husbandry 85
Veterinary Science 87
Waltham Field Station 90

Cooperative Investigations:

Cranberry 40
Tobacco 14
Publications 92

ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION – 1936

INTRODUCTION

F. J. Sievers, Director

Changes in economic and social conditions should find expression in modifying the operations of research agencies primarily established to serve the general public. It is hoped that the Experiment Station administration will never lose sight of this fundamental fact. Even though it may not appear that, in the main, there is any change in the projects under investigation there is, nevertheless, a continual expansion of service into new fields and a retraction from those activities no longer considered of foremost importance.

As a result of a re-evaluation of contemplated services to satisfy the desires for increased research in nursery culture at the Waltham Field Station, it was considered the part of wisdom to temporarily forego the utilization of the appropriation made last year for expansion and equipment in the hope that reconsideration would find approval for an enlarged appropriation such as is included in the present budget requests. In the meantime, our research program has not only been put into operation but is serving very effectively under the leadership of Professor George Graves and Mr. Harold S. Tiffany.

The demand for service in vitamin values of foods has taken on proportions quite beyond what was anticipated when the Nutrition Laboratory was first provided and partially equipped. This laboratory has afforded a means for a very desirable type of cooperation among members of several departments in the college and its effectiveness is already attracting quite general attention. During the year an amount of $5,000 was especially allotted to the Experiment Station for the purpose of adding encouragement to the activities in that phase of nutrition which deals with some of the numerous human deficiency disorders. This donation, obtained largely through the activities of Dr. Joel E. Goldthwait, has been designated the Mrs. Henry Lang Fund in honor of the donor. The American Medical Association has also expressed its recognition of our service by making a voluntary financial contribution to the support of another phase of the work.

At the Cranberry Field Station, our attempts at solving some of the management problems, especially as these relate to weed control, have been instrumental in impressing the members of the Cranberry Growers' Association sufficiently to cause this organization to appropriate the sum of $500 for the purpose of giving special encouragement to work in that field.

All of these reactions which, in themselves, are very complimentary, nevertheless become somewhat embarrassing when we find ourselves continually in a position where we need to be apologetic for not being able to serve adequately, those who have a right to make requests. At present, there are demands before us from the Massachusetts Arborists Association to assist them in establishing a sound basis for dealing with the numerous entomological, pathological, and physiological problems confronting them in their attempts to preserve and enhance the natural horticultural beauties of the State.

The greenkeepers, too, are very active in soliciting our aid in the solution of the many problems confronting those who have the direct responsibility for providing such golfing facilities as a recreation-conscious public is increasingly demanding.

The poultry interests in the State are very urgent in requesting our assistance in providing them with certain information and protection regarding many of the claims made for vitamin values of poultry feeds. Such services are already fairly well established in some of the other states, and analytical methods in this field are rapidly becoming a part of Feed Control regulations. Sooner or later, the State of Massachusetts will need to deal with this matter, and it is hoped that Legislative approval may be gained for an item at present included in our budget for the purpose of establishing a small laboratory in which the several feeds may be put to direct feeding tests.

To meet these and several other definite demands requires an expanding budget and it was planned that the gradual enlargement in funds available from federal Bankhead-Jones sources might enable the Experiment Station to meet these needs. Unfortunately, however, present recommendations, as prepared by the Budget Commissioner, fall very decidedly short of meeting even the financial requirements of the program already in operation. To be faced with the need for curtailment at a time when we are confronted with these increasing demands for service will induce some of our agricultural groups to seek direct action in obtaining legislative appropriations. This type of expansion does not necessarily make for the most satisfactory program; but unless the Legislature, through its advisors, realizes the need for taking the initiative, there is sure to be an attempt to confront it regularly with demands for comparatively large increases in our financial support.

The unemployment situation during the depression and the experiences in providing means for temporary relief in the hope of promoting recovery have furnished adequate proof that much national planning is necessary if such future low levels in our economic and social life are to be avoided. It is evident that public works projects as inaugurated, not only locally but nationally, ranked foremost in their constructive value. Since it is generally recognized that periods of prosperity are regularly followed by depression lows much the same as hills alternate with dales, it would appear the part of wisdom to anticipate and plan for the next depression now that the country is well on the way to recovery. Such planning, to be sound, requires not only all the wisdom available but, what is even more essential, an unprejudiced approach. Such assignments are not new to agricultural experiment stations in their function as public service agencies and it is not only natural but highly desirable that they should take a very active part in the development of a sound and permanent program for dealing with problems of unemployment and general economic and social sickness.

The soil conservation program, as organized under the federal administration, is one of those plans that is sure to find a very practical and permanent place after some of the political prejudices and the primary administrational difficulties have been overcome. Naturally, such a program is decidedly influenced by local conditions. The United States represent all extremes in variations in the agriculture of the northern temperate zone. These extremes are further influenced by such artificial economic factors as always have a significant bearing on the practical phases of any industry. Most of the problems, therefore, are more or less unique to a region within the area and local authorities will find it necessary to exert considerable leadership if the service is to become effective and worthy of respect and enthusiastic support.

In this connection, it should first be established that soil conservation is justified as a public policy. In the past, we have been inclined to assume that this was the obligation of the individual farmer. His natural interest in posterity was supposed to furnish the initiative for keeping the farm in a high state of productivity. This is a splendid ideal and, no doubt, one that makes a strong appeal, especially in areas where many of the sentimental values of ownership and possession are recognized. Unfortunately, however, the business of farming has become so decidedly competitive in recent years that the responsibility of providing for the immediate requirements of the farmer and his family has taken on tremendous proportions. This tendency naturally crowds all interest in the conservation of soil productivity into the background. As a result, our soils have deteriorated through erosion and general exhaustion at a very rapid rate and there is definite realization that this is a matter deserving of the constructive interest and support of the entire consuming public if our standard of living is to be maintained. The fertility of the soil is, without doubt, our greatest natural resource. Our present and future prosperity is largely dependent upon it. It must be conserved. If the individual farmer does not accept this responsibility the nation must. The State of Massachusetts, while in general fairly sound in its soil management program, thanks to its favorable natural conditions, nevertheless has its problems in this connection. The Experiment Station is attempting to assume some of the responsibility for leadership which these problems require.

AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

An Economic Study of Secondary Milk Markets in Massachusetts. Group I — Connecticut Valley. (A. A. Brown, C. R. Creek, and J. E. Donley.) An earlier survey defined secondary markets as cities or towns, with the exception of Metropolitan Boston, with populations of 10,000 or more. Results of the present study tend to confirm the opinion held by various groups that the corporate limits of such municipalities are unsatisfactory boundaries for a market. On the basis of data secured from dealer license applications, the Springfield market has been determined as an area composed of nine towns and four cities.

Just as markets are not necessarily delineated by city lines, neither are milksheds for given markets distinct one from the other. The milkshed for the Springfield area extends chiefly to the north and northwest, although a few towns to the south and east are a part of it. Within this shed of 119 towns in five states, are three smaller markets with their sheds, plus a group of farmers whose production goes to Boston.

An experimental study was made of the net farm prices, deliveries, butterfat tests, and trucking charges of the producers shipping to Northampton. The wide range in price, the relatively small number of producers in the various price classes, the scattered location of the producers, the low percentage of producers in a given area who ship to Northampton, the fact that a predominantly college market has characteristics not common to all, necessitated extreme qualification of any conclusions which were drawn. With these limitations, there is little rationality to the structure of net farm prices for that portion of the shed. Trucking and trucking charges, deliveries, and butterfat tests for producers supplying Northampton are subject to the same limitations as net prices, although not in as high degree.

More satisfactory results can be realized by analyzing the shed in its entirety. Approximately 2,300 producers in this milkshed supply the four secondary markets and a Boston milk plant. Of this number, roughly 1,900 produced for the Springfield market area in 1935. A complete record for 1935 is available to date for only 90 percent of the milk. It is expected that selected ratios, such as seasonal variation in production, butterfat test, and market sales, determined on the basis of this volume will hold even after adjustments have been made for the balance.

Average daily deliveries for this volume of milk showed a 25 percent variation, from 200,000 pounds in November to 251,785 pounds in June. These quantities do not represent the smallest nor the largest day's receipts in 1935. They indicate that every day in November deliveries tended to be lower than daily deliveries in any other month of the year. And in the opposite direction, every day in June deliveries tended to be higher than daily deliveries in any other month.

The months of highest and lowest average daily sales by dealers did not correspond to the months of highest and lowest average daily deliveries by producers. Average daily sales varied from 134,556 pounds in August to 157,645 pounds in March — a range of 17.1 percent.

Average daily surplus was lowest in January when sales were above the August level and deliveries were appreciably lower than in June.

A Study of Farm Organization and Soil Management Practices in Massachusetts in Relation to Agricultural Conservation and Adjustment, with Special Reference to the Formulation of a Program under the Soil Conservation and Domestic Allotment Act. (C. R. Creek, in cooperation with the Departments of Economics and Agronomy.) The results of this project are reported in full elsewhere (see report of the Department of Economics). The records taken on 113 dairy farms in ten counties showed that 58 farms had only seeded pasture fields which had been improved by fertilizing treatment. The pasture on 19 farms had been treated with fertilizing materials but had not been seeded. On 36 farms both seeded and non-seeded pasture had been fertilized. On the majority of farms the seeded and fertilized pasture fields yielded many more days of grazing per acre than did the non-seeded fertilized pasture. Comparisons were made of the grazing secured from annual pasture, rowen pasture, and open untreated pasture as well as that from the treated pastures.

The effect of pasture improvement and other factors upon farm organization and operation is being studied more intensively on four farms. A case study of each farm for the year prior to any pasture improvement and for the year 1935 is in progress now, in an effort to determine the economic feasibility of pasture improvement as well as its place in a land conservation program. The desirability and need of pasture improvement as a soil conservation practice is also being studied.

DEPARTMENT OF AGRICULTURAL ENGINEERING

C. I. Gunness in Charge

Low-lift Pumps for Cranberry Bogs. (C. I. Gunness.) Tests have been conducted on a low-lift pump built by a Massachusetts manufacturer to meet the needs of cranberry growers. The pump gave a maximum efficiency of 80 percent, which is well above the performance of most pumps now used on cranberry bogs.

Milk Cooling. (C. I. Gunness and W. H. Tague.) Tests have been conducted on a tank with cooling coils concentrated within a duct through which the water is drawn by a circulating pump. The water is sprayed on to the milk cans in order to give proper cooling at times when the cooling water is below the neck of the cans. This arrangement of coils permits a very low temperature difference between refrigerant and tank water, and the spray cools the milk to 50° within one hour, even when the water is 3 inches below the neck of the can. On the strength of these results, one manufacturer has incorporated these improvements in his milk cooling tanks and the equipment is now on the market.

Cranberry Storage. (C. I. Gunness in cooperation with the Cranberry Station and the Department of Horticultural Manufactures.) A study of cranberry storage was started on samples collected from the 1936 crop. Some of these berries are still in storage, but results to date indicate economic possibilities for the storage of berries at temperatures ranging from 35° to 50°.

Brooding. (C. I. Gunness in cooperation with the Department of Poultry Husbandry.) A project was started in the spring of 1936 to determine the optimum temperature, humidity, and rate of air circulation for brooders. A large brooder, electrically heated, is used in the experiments, affording ample space and a wide range of air conditions for the chicks. No results can be reported from this investigation until the end of the present brooding season.

Investigation of Apple Storages. (C. I. Gunness in cooperation with the Department of Pomology.) The work on apple storages has been continued. The results from this study were reported quite fully in the 1936 report. Additional data have been collected during the past year and a bulletin on apple storages is now being prepared.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Tobacco Projects. (Walter S. Eisenmenger and Karol J. Kucinski.) *Cropping Systems.* Tobacco grown in rotation with other crops is frequently infected with a disease called brown root-rot. Studies have shown that the chances for serious infection following certain crops are much less than when tobacco follows certain other crops. It would seem, therefore, that the most satisfactory control for the disease on tobacco grown in rotation is to precede tobacco with a crop which will reduce the chances of serious infection to a minimum. For the past two years, results have indicated that satisfactory tobacco can be expected following potatoes and red top. The basis for comparison included quality, yield, and appearance of roots.

The following represent the yields from different treatments:

Plot Treatment	Number of Plots	Average Yield per Acre Pounds
Red top cover	6	2,153
Check (limed)	5	2,089
Check (no lime)	5	2,197
Orchard grass cover	6	2,124
Spinach cover	6	2,084
Tall meadow oat grass cover	6	2,128
Italian rye grass cover	6	2,104
Manure (no cover)	4	2,207
2d year tobacco after potatoes	1	2,046
1st year tobacco after 1-year-old orchard grass	4	1,558
1st year tobacco after 1-year-old timothy sod	1	1,739
2d year tobacco after manure and 1-year-old red top	2	2,352
Tobacco after manure and red top cover	2	2,222
1st year tobacco after red top and clover hay, 2-year sod	1	2,352
1st year tobacco after 2-year-old red top sod	1	2,252
1st year tobacco after 2-year-old sod of timothy and clover	1	2,423
1st year tobacco after 2-year-old sod of timothy	1	2,242
1st year tobacco after 1-year-old sod of red top and clover	1	1,779
1st year tobacco after 1-year-old sod of red top	1	2,021

Excellent yields were obtained this past season from plots in which tobacco followed lamb's quarters (*Chenopodium album*) and pigweed (*Amaranthus retroflexus*) and from a small plot of electrically sterilized soil. These soils had been cropped previous to this experiment with four successive years of corn.

In the spring of 1935 one portion of the field was sown with lamb's quarters, another portion with pigweed, and the remainder again planted with corn. In the spring of 1936 the soil of a part of the field where corn had previously grown was electrically sterilized. The soil was removed to a depth of six inches, placed in a box connected with terminals, sterilized at a temperature of 100° C. or above, and replaced in the field when the process was completed. In another part of the field where corn had been grown, mature tobacco plants were left in the field over winter and plowed under in the spring of 1936.

Tobacco was grown on the field in 1936, with results as follows:

	Average Yield per Acre Pounds
Tobacco following corn	2,110
Tobacco following corn (mature tobacco plants plowed under)	2,195
Tobacco following lamb's quarters (*Chenopodium album*)	2,427
Tobacco following pigweed (*Amaranthus retroflexus*)	2,682
Tobacco on sterilized plot	2,564

Spacing Experiments. An experiment to attempt to determine the effect of spacing on yield and especially on the contour and thickness of leaves of tobacco was carried on during the past year. Not all of the data have as yet been taken, as to quality, desirable shape, etc., but the yields are included in the following: (the distance between rows is indicated; the two types of tobacco used are common Havana and No. 13, a type more resistant to black root-rot (*Thielavia basicola*).

Distance between Plants	Average Yield per Acre			
	Rows 36 inches apart		Rows 39 inches apart	
	Variety No. 13	Common Havana	Variety No. 13	Common Havana
15	2,022	2,068	2,331	2,037
18	2,114	2,140	2,013	1,739
21	1,984	1,864	1,992	1,437
24	2,054	1,884	1,926	1,707
27	2,094	1,631	1,801	1,537

The Reaction of Plants Grown in the Field toward the Subsequent Tobacco Planted in Rotation. (Walter S. Eisenmenger and Karol J. Kucinski.) It has been a conjecture of the writers that there was a possible relationship between the botanical species and rate of ammonification and nitrification of plant tissue and the capacity to induce brown root-rot when different plants were grown in rotation with tobacco.

All the grasses tried with the exception of red top are conducive to the occurrence of the trouble. Red top decomposes the most slowly of all the grasses used in rotation.

The *Solanaceae*, potatoes, tomatoes, etc., do not seem to induce the trouble. They decompose exceedingly rapidly to ammonia and nitrate nitrogen. Ragweed and horseweed decompose fairly rapidly, and do not induce the malady.

On a field this year were planted the following varieties of plants: horseweed, alfalfa, Canada bluegrass, Kentucky bluegrass, sweet clover, orchard grass, red clover, rye, wheat, artichoke, red top, ragweed, gladiolus, turnip, tomato, pepper, cabbage, squash, sudan grass, sorghum, buckwheat, carrots, millet, and seaweed (applied). The relative rate of ammonification and nitrification of these plant tissues is known from previous experiments.

In 1937, tobacco will be planted where (on four plots of each plant) these plants were grown in 1936.

Magnesium Requirements of Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) Parts of a field known to be deficient in magnesium were used to determine the relative response and tolerance of different crops to this element. A mixed fertilizer containing no calcium or magnesium was applied to the entire field, and magnesium sulfate and ground limestone were added as follows: Plot A — none, Plot B — magnesium, Plot C — magnesium and lime, Plot D — lime.

The differences in appearance during the growing period were marked. Differences in yield, expressed as pounds per acre, are shown in the following table:

Plot	Mangels	Rutabagas	Potatoes		Corn		Buckwheat	Barley*	Oats*
			Pounds per A	Percentage of Seconds	Stover Dry	Ears Dry			
A — None	32,231	38,287	7,492	28.85	2,544	1,918	1,611	3,458	7,092
B — Magnesium	42,390	42,430	14,481	23.81	3,755	3,746	2,037	2,824	4,705
C — Magnesium and lime	48,167	51,474	17,435	13.22	3,310	3,033	2,278	2,025	3,078
D — Lime	31,076	45,776	16,811	15.71	2,955	3,462	2,039	3,497	2,997

*These crops may have been affected during the dry summer by a gravelly slope running through the plots.

The Absorption by Food Plants of Chemical Elements Important in Human Nutrition. (Walter S. Eisenmenger and Edward B. Holland.) Salts of iron, copper, manganese, and iodine were applied to plots growing spinach, lettuce, onions, beets, and carrots. Ferric oxide applied did not increase the amount of iron in the plants. The hydrogen-ion concentration of the soil is probably more of a factor in iron assimilation than is the amount of insoluble iron compound present. Applied copper increased the amount of copper in most plants over that found in the checks. Manganese gave inconsistent results as to amounts in plants in the manganese plots and in other plots. Iodine in the plants was not determined.

There was ample evidence that applications of manganese tend to increase the amount of phosphorus in the plants.

Time of Cutting Alfalfa. (Walter S. Eisenmenger and Karol J. Kucinski.) An alfalfa field of rather even stand was cut at different times to determine the best returns in yields. Eight plots were cut three times and four plots were cut twice. The higher yields were associated with those cut three times. The highest yield was obtained when the first cuttings were made on June 13, the next on August 1, and the last on September 1.

Proportion of Mixtures used in Seeding for Hay. (Walter S. Eisenmenger, Ralph W. Donaldson, and Karol J. Kucinski.) Alfalfa, red clover, timothy, orchard grass, and red top were seeded in different proportions. The three totals in pounds per acre of seed applied were 21, 17, and 13, and thirteen different combinations at each of these rates were seeded. Thus there were thirty-nine (39) variations. This year the seeding at the rate of 17 pounds per acre yielded 17,130 pounds of hay. This was the maximum for two cuttings. The hay contained 61 percent of red top and 39 percent of alfalfa. One of the lowest in yield was the plot where 13 pounds of seed were used and the hay contained 100 percent alfalfa. The yield for two cuttings was 10,539 pounds.

Alfalfa Variety Tests. (Walter S. Eisenmenger and Karol J. Kucinski.) In cooperation with the United States Department of Agriculture, tests are being conducted with fifteen varieties of alfalfa. Two varieties for this year, Ladak and Hardigan, seem to have promise for yields, while such varieties as Utah and Oklahoma Common do not as yet yield adequately.

Potato Variety Tests. (Ralph W. Donaldson, Walter S. Eisenmenger, Arthur I. Bourne, and Karol J. Kucinski.) The variety test for comparison of yields was continued this year on the experiment station farm. Each plot received eleven applications of Bordeaux mixture, 5–5–5. The yields compared on the basis of bushels per acre are as follows:

	1936	*1935*
Green Mountain	449.4	444
Russet Rural	429.5	384
Golden	397.9	280
Chippewa	384.0	542
Katahdin	329.1	423
Irish Cobbler	319.8	—

The Comparative Nutritive Effects of Copper, Zinc, Chromium, and Molybdenum. (H. Robert DeRose, Walter S. Eisenmenger, and Walter S. Ritchie.) In carefully purified white sand washed with aqua regia and later washed with water and then heated at 100° C., tomatoes, buckwheat, and barley were planted in crocks with capacity to drain at the bottom. Knop's solution was used and allowed to drain through at the rate of 1 liter in 24 hours. All chemically pure salts were recrystallized. Copper was used at the rate of 0, .05, .15, .50, 1.0, and 5 parts per million of sand; and zinc at the rate of 0, .05, .10, 10, and 30 parts per million of sand.

The preliminary results clearly indicated that .05 and .15 parts of copper per million were decidedly stimulating to tomato plants. The extreme care in purification resulted in the relative absence of boron, the results of which were visible on the meristem of all tomato plants. One or more parts per million of copper were decidedly toxic to tomato plants, as were also ten or more parts per million of zinc.

Distribution of Nitrogen in Soils Mixed with Different Plant Tissues and Allowed to React for Two Months. (Walter S. Eisenmenger.) Tobacco planted in rotation with corn or timothy is frequently subject to brown root-rot, while tobacco following tobacco and certain weeds, such as ragweed and horseweed, seems less susceptible to the disease.

The ground tissues of tobacco, ragweed, horseweed, red top, corn, and timothy were placed with soil in crocks in the greenhouse in quantities so that each contained equal amounts of nitrogen. They were allowed to stand for two months.

It was found that the total nitrogen at the end of the reaction period was higher for timothy, corn, and red top.

In general, the water soluble nitrogen was higher for corn, timothy, and red top.

Nitrate nitrogen was higher in the crocks containing horseweed, ragweed, and tobacco as was also amide nitrogen.

Protein and ammonia nitrogen were higher in the crocks containing timothy, red top, and corn.

No particular relationship was indicated for alpha amino acid and humin nitrogen.

The object of the experiment was to attempt to correlate conditions obtained in the field with those in the laboratory.

Pasture Experiments. (William G. Colby.) The schedule of fertilizer applications was maintained on the seven permanent pasture plots in Worcester County. Mid-season observations showed that the greatest response was to "complete fertilizer," although the response to nitrogen and lime was nearly as great. In the applications of single elements, the greatest response was to nitrogen, followed in turn by lime, potash, and phosphorus. In no case was there abundant growth of white clover. Although treated for several years with mineral fertilizers, none of the plots had established a really good pasture sod. Either the soil fertility level had not yet been raised sufficiently high to support the best type of pasture vegetation or some other mineral elements necessary for plant nutrition were deficient. It is evident from these experiments that the problem of renovating permanent pasture sods is still a live one.

Pasture Breeding. (William G. Colby and Hrant M. Yegian.) Breeding work with several common species of perennial pasture plants was begun with the extensive collecting of seed from many old pasture fields. The superior strains of this material supplemented with improved strains of the same species introduced from other regions will constitute the basic stock to be used for extended breeding operations.

Onion Breeding. (William G. Colby and Hrant M. Yegian.) The past summer was decidedly unfavorable for breeding work. Seed production was poor, and bulbs produced from "sets" and "transplants" suffered severely from "blast." However, more than 400 lots of bulbs were produced from seed and several of these lots showed promise of being superior in type and quality. One strain showed several bulbs segregating for a leaf type similar to that of the Sweet Spanish onion. Since the Sweet Spanish onion seems to show greater resistance to thrips injury, the finding of this leaf character segregating in the breeding material appears significant.

Experimentation with Artificial Manure. (Karol J. Kucinski and Walter S. Eisenmenger.) Certain phases of the experiments with artificial manures reported in 1935 were continued. As a possible way to get rid of household garbage and leaves, and at the same time put them to good use, a combination of these materials was used in making artificial manure. The addition of the garbage to the leaves, besides greatly aiding and hastening the decomposition, made the manure a richer plant-food carrier.

Several of the different kinds of artificial manures were applied as top-dressing to a mixed hay field. The percentage of clover in the stand and the yields increased greatly on the treated plots. The yields are listed below.

Yield of Hay Grown on Plots with Artificial Manure Top-Dressing

Plot treatment with manure made from —	Yields on dry basis Pounds per Acre
Straw and cyanamid	5,101
Corn stover and cyanamid	5,227
Straw and ammonium sulfate	4,541
Garbage with leaves and cyanamid	6,265
Untreated plot	3,363

The plant nutrients in the various artificial manures were determined by chemical analysis and are reported in Table 1.

TABLE 1. — PLANT NUTRIENTS IN ARTIFICIAL MANURE

"Oven-Dry Basis" 110° C.

Manure made from —	Weight of wet manure pile Pounds	Oven-Dry Manure		Oven-Dry Basis		
		Pounds	Percent	Nitrogen Percent	P_2O_5 Percent	K_2O Percent
Corn and ammonium sulfate	2,965	568	19.16	1.85	1.58	2.50
Corn and cyanamid	3,433	746	21.74	1.96	1.68	2.52
Straw and ammonium sulfate	2,880	540	18.76	2.21	1.62	2.75
Straw and cyanamid	2,723	533	19.59	2.58	1.59	2.51
Leaves and ammonium sulfate	2,671	727	27.22	1.80	1.20	1.15
Leaves and cyanamid	2,513	724	28.81	1.72	1.56	1.20
Leaves, garbage and cyanamid	—	—	28.49	3.08	4.14	3.20

Enough of each organic material was used to supply 1,000 pounds of dry matter.

In order to study the reason for the slow rate of decomposition of leaves when they are used in making artificial manure, lignin and cellulose determinations were made, with results shown in Table 2. The percentage of lignin was greater in the leaves than in the corn stover or straw. The percentage of cellulose, on the other hand, was greatest in the straw and least in the leaves. The analyses of the finished manure show that the rate of decomposition of the cellulose was much greater than that of the lignin.

TABLE 2. — LIGNIN AND CELLULOSE IN ARTIFICIAL MANURES

	Lignin Percent	Cellulose Percent
Original leaves alone	19.16	26.37
Manure from leaves, garbage and cyanamid	16.16	8.88
Manure from leaves and ammonium sulfate	31.00	12.57
Manure from leaves and cyanamid	29.60	10.20
Original corn alone	13.10	37.58
Manure from corn and ammonium sulfate	17.58	22.24
Manure from corn and cyanamid	16.91	18.34
Original straw alone	15.76	44.41
Manure from straw and ammonium sulfate	24.03	21.83
Manure from straw and cyanamid	23.08	19.70

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in Cooperation with the Massachusetts Agricultural Experiment Station.

C. V. Kightlinger, U.S.D.A., in Charge

Black Root-Rot. (C. V. Kightlinger.) Three of the thirty-six strains of Havana Seed tobacco tested comparatively during the preceding five years of investigation, were selected for further testing in 1935. This was done in continuation of the attempt to find strains which may be acceptable under Connecticut Valley conditions for resistance to black root-rot, and for type of plant, type and quality of leaf, gross yielding capacity, and such other properties as may be necessary in order that the strains may be acceptable to tobacco growers and cigar manufacturers.

Two strains of Havana Seed tobacco which possess between them in acceptable degrees those properties which the new strains must combine in order to fulfill the objectives of the investigation, were grown for control purposes in these tests. One strain was Havana Seed of the sort that is grown most commonly at present in the Connecticut Valley. When grown under favorable tobacco-producing conditions, this strain is ordinarily satisfactory for type of plant, type and quality of leaf, and gross yield of tobacco ordinarily acceptable to cigar manufacturers. However, like all other strains of common Havana Seed tobacco, it is sufficiently susceptible to black root-rot to make its use unsatisfactory, when it is grown under soil conditions suitable for the development of the disease. The other strain was Havana Seed 142A3. This strain, although not immune, is nevertheless highly resistant to black root-rot and ordinarily is acceptable for gross yields when it is grown under soil conditions that are suitable for the development of the disease. It produces more heavily under black root-rot free conditions. Unfortunately this strain is not entirely acceptable for type of plant and type and quality of leaf produced, even when it is grown under favorable tobacco-producing conditions; and the tobacco produced by the strain is not acceptable in most cases to tobacco leaf dealers and cigar manufacturers.

The three strains of tobacco selected for further testing in 1935 were Strains 13, 29 and 33 according to their small-plot test numbers, or Strains A211A2, A236A5 and B202–12, respectively, according to their pedigree numbers used in the practical production and demonstrational tests. The smaller numbers have been used in the small plot experimental testing as a matter of convenience. The respective pedigree numbers and the corresponding small-plot test numbers of these strains are both mentioned here for the sake of clearness in associating published results of the small plot experimental testing and current unpublished results of demonstrational testing. Two of the strains have been tested in practical production in cooperation with tobacco farmers and with cigar manufacturers under their pedigree numbers during the time they were being tested in small plot experiments under their corresponding small-plot test numbers. If they prove to be acceptable to cigar manufacturers, they will be distributed for general use under their respective pedigree numbers.

Strain 13 has been tested in small plot experiments for six years, including 1935, under black root-rot free conditions and for five years under soil conditions suitable for the development of the disease. Strains 29 and 33 have been tested in small plot experiments for three years, including 1935, under black root-rot free conditions, and for four years and three years, respectively, under soil conditions suitable for the development of the disease. Strains 13 and 29 have been tested for three years and one year, respectively, in practical production in cooperation with tobacco farmers. Strain 33 has not yet been tested in practical production.

These strains rate high in most respects according to the small plot experimental tests and the standards of comparison and evaluation employed for rating new strains. They differ, however, in the degree to which they possess some essential properties and some minor but desirable properties.

Experimental results show that Strain 13 is highly resistant to black root-rot, and that it yields a satisfactory amount of good tobacco under soil conditions suitable for the development of the disease. It ordinarily yields more heavily under disease-free conditions. It possibly may yield more tobacco under favorable producing conditions than some growers can sometimes handle and care for most conveniently. Due to its vigorous growing habits, the strain needs more space per plant than may be necessary for common Havana Seed tobacco. Tests have shown that it cures most satisfactorily when it has been ripened thoroughly. Tests have shown, also, that it may be permitted to ripen is upper leaves thoroughly, and at the same time improve the body of its lower leaves and have little or no dying of these leaves result during the ripening process. As a result, the strain produces its best tobacco when it has been permitted to ripen thoroughly before being harvested. Experimental results show that it cures as readily and as well as common Havana Seed tobacco of approximately the same yield and maturity, grown under the same conditions. The strain is wider leafed than most strains of common Havana Seed tobacco. It might possibly be improved somewhat in type of leaf, if the butt portion of its leaves, and especially its lower leaves, grew somewhat narrower. However, the strain is acceptable in most respects for type of plant and type and quality of leaf. Except for its more vigorous growing habits and its larger size, it closely resembles common Havana Seed in general appearance while growing in the field, and in its cured condition, as well. Its date of maturity is little, if any, later than that of most strains of common Havana Seed tobacco.

Experimental results show that Strain 29 is highly resistant to black root-rot, and that it yields a satisfactory amount of tobacco under soil conditions suitable for the development of the disease. It ordinarily yields more heavily under disease-free conditions. It, also, may possibly yield more tobacco under favorable producing conditions than some growers can sometimes handle and care for most conveniently. It exceeds Strain 13 in these respects. Like Strain 13, it needs somewhat more space per plant than may be necessary for common Havana Seed tobacco, and cures best when it has been ripened well. It will not, however, withstand ripening to the same degree that Strain 13 will, without injury resulting to some of its lower leaves. It is much like Strain 13 in its manner of curing. It is somewhat less satisfactory than Strain 13, tor type of plant and type and quality of leaf. It is wider leafed than most strains of common Havana Seed tobacco, and like Strain 13, might be somewhat improved in type of leaf, if the butt portion of its leaves, especially its lower leaves, grew somewhat narrower. The strain resembles common Havana Seed tobacco less closely in general appearance than Strain 13 does. Its date of maturity is a few days later than that of Strain 13 and most strains of common Havana Seed tobacco.

Experimental results indicate that Strain 33 is somewhat less resistant to black root-rot than Strains 13 and 29, and the resistant control strain. It does not yield so heavily as these other strains do, under soil conditions suitable for the development of the disease, but it produces a good quality tobacco under these conditions. It does not yield so heavily under favorable producing conditions as Strains 13 and 29 do, but it ordinarily produces enough tobacco under these conditions to be profitable. It is satisfactory for type of plant, and type and quality of leaf. It does not grow so wide butts of lower leaves as Strains 13 and 29 do, and is more satisfactory in this respect. The strain closely resembles common Havana Seed tobacco in general appearance while growing in the field as well as in its cured condition. Its date of maturity is about the same as that of Strain 13 and most strains of common Havana Seed tobacco.

Practical testing of Strains 13 and 29 in cooperation with tobacco growers showed these strains to have merit. Both strains seemed to be acceptable to most of the growers who grew them in cooperative trials. Strain 13 proved to be promising enough to receive serious consideration and rather complete testing by cigar manufacturers to determine its acceptability from their point of view. Their decision on the matter has not yet been made.

It seemed, in 1935, that the greatest need in further work with the strains was more complete testing in small plot experiments to make certain that the strains were not being estimated wrongly; and more extensive testing in cooperation with tobacco growers and with cigar manufacturers, to determine the acceptability of strains for practical purposes. Accordingly the strains were grown in 1935 in well-organized and closely supervised small plot experiments, and in practical production tests in cooperation with tobacco farmers. Strain 13 was continued in practical production tests in cooperation with tobacco farmers and in demonstrational trial testing by the cigar manufacturers, in 1936.

The production data of Strains 13, 29 and 33, and the controls for the periods of time and under the conditions indicated, are as follows:

Strains	Grown on black root-rot free land				Grown on black root- rot land			
	Year of test	Average yield per acre (pounds)	Average grade index	Crop index	Year of test	Average yield per acre (pounds)	Average grade index	Crop index
			I. For 1935					
Common strain	1935	2049	.379	777	1935	1345	.332	447
142	—	—	—	—	1935	1785	.379	677
13	1935	2222	.390	867	1935	1912	.402	769
29	1935	2235	.383	856	1935	1924	.381	733
33	1935	1970	.386	760	1935	1690	.374	632
			***II. For duration of tests of respective strains**					
Common strain	1930–35	2050	.411	843	1931–35	1331	.314	418
142	—	—	—	—	1931–35	1855	.365	677
13	1930–35	2214	.462	1023	1931–35	1938	.406	787
29	1933–35	2358	.413	974	1932–35	2032	.389	790
33	1933–35	1955	.423	827	1933–35	1684	.389	655
			III. For identical periods of time					
Common strain	1933–35	2146	.393	843	1933–35	1452	.338	491
142	—	—	—	—	1933–35	1842	.377	694
13	1933–35	2273	.429	975	1933–35	1921	.415	797
29	1933–35	2358	.413	974	1933–35	2024	.405	820
33	1933–35	1955	.423	827	1933–35	1684	.389	655

*See explanation in text.

Grade index, as used here, is a number expressing the grading quality of tobacco produced under the conditions of the experiment. It is based upon the percentage yield of each grade of tobacco and the relative values of these grades of tobacco, given below:

Lights	1.00	Long darks (19″ and longer)	.30
Mediums	.60	Dark stemming (17″ and shorter)	.20
Long seconds (19″ and longer)	.60	Brokes	.10
Short seconds (17″ and shorter)	.30	Fillers	.10

The grade index is derived by multiplying the percentage of each grade of tobacco by the respective rating of the grades, given above, and adding the products.

Crop index, as used here, is a number expressing the crop value of tobacco produced under the conditions of experiment. It is based upon the gross yields of tobacco in pounds per acre and the grade index of the tobacco. Crop index is derived by multiplying the gross yield of tobacco in pounds per acre by the grade index of the tobacco.

Grade index and crop index and the adopted relative values of the different grades of tobacco, as used here, do not necessarily represent current commercial prices of tobacco.

The average measurements and determinations of types of plants and leaves produced by Strains 13, 29 and 33 and their controls, for the years indicated, when the strains were grown under favorable tobacco-producing conditions, are as follows:

Strains	Height of plants topped high (inches)	Number of leaves per plant	Length of internodes (inches)	Length of leaves (inches)	Width of leaves (inches)	Diameter of stalks topped high	
						Butt (inches)	Top (inches)
I. For 1934							
Common strain	35.9	17.1	2.1	27.8	12.8	1.4	0.8
142	33.9	19.1	1.8	26.0	12.3	1.3	0.8
13	38.9	16.9	2.3	28.5	15.0	1.4	0.8
29	39.0	18.5	2.1	26.5	13.8	1.3	0.8
II. For 1935							
Common strain	36.7	17.8	2.1	26.7	13.1	1.4	0.8
142	38.9	20.0	1.9	25.3	13.0	1.3	0.7
13	42.6	17.5	2.4	27.8	14.9	1.4	0.6
29	43.7	19.9	2.2	26.7	13.9	1.4	0.7
33	40.9	16.8	2.4	27.9	14.9	1.4	0.7

Additional data on the comparative shape of leaves of these strains of tobacco grown in 1934 and 1935, but not given here on account of their detailed nature, showed the average shape of leaves produced by Strains 13, 29 and 33 under similar conditions to be approximately the same. The leaves produced by these strains were wider at mid-length in comparison to their entire length, than were the leaves produced by the common Havana Seed strain and Strain 142A3 under similar growing conditions.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

The Relative Efficiency for Milk Production of Proteins from Animal and Vegetable Sources. (J. G. Archibald, V. A. Rice, and C. H. Parsons.) Results of the second phase of this project, on the suitability of dried blood as a source of protein for milk production, have been published in Bulletin 334, entitled "Dried blood as a source of protein for milking cows."

The Effect of Feeding a Vitamin A Concentrate on Reproduction in Cattle. (J. G. Archibald, V. A. Rice, and C. H. Parsons.) This project has been continued throughout the year and present plans are to bring it to a conclusion at the end of the barn-feeding season in the spring of 1937. A survey of progress made in June of this year led to the following tentative conclusion: the benefit from the vitamin concentrate, if there be any, seems to be reflected in birth weight and growth rate of the young calves rather than in the growth of heifers after they have passed the calfhood stage of their existence or in the reproductive record of either heifers or mature cows.

The Effect of Complex Mineral and Vitamin Mixtures on Milk Production, General Health, and Reproductive Efficiency in Dairy Cattle. (J. G. Archibald.) This project, organized in April of this year, is being conducted cooperatively with the State Department of Mental Diseases, the milking herds at three of the State hospitals being utilized for the work.

The object is to determine by carefully conducted feeding trials with large numbers of animals whether mixtures of the nature indicated above have any merit for the purposes for which they are sold. Approximately 190 cows are included in the experiment, which will be continued for at least one complete lactation period of all or practically all the individuals. Results will not be available for at least another year.

A Study of the Mineral Elements of Cows' Milk. (J. G. Archibald, V. A. Rice, and C. H. Parsons.) This project, recently organized, has for its objectives answers to the following questions:

(1) Can the amounts of the mineral elements normally presents in cows' milk be significantly increased by modification of our feeding practices?

(2) Can milk be "fortified" in those respects in which it is sometimes considered to be relatively deficient, by the feeding of certain elements such as iron and manganese?

(3) If these objectives can be accomplished, what significance have they from the standpoint of human nutrition? In other words, what may be the effect upon human well-being of milk so "fortified"?

For the present, attention is concentrated on the element calcium. Ten cows in the college herd have been divided into two groups of five each, in one of which the cows are receiving supplemental calcium in the form of finely ground limestone in amount roughly equivalent to that naturally occurring in their rations. Composite milk samples are taken once a month for a two-day period and the calcium determined by a method specially devised for the detection of small differences. At the end of three months the groups will be reversed so that the cows not now receiving supplemental calcium will receive it for a similar three-month period later in the winter.

The Effect of Artificial Light on Milk Production. (J. G. Archibald, V. A. Rice, and C. H. Parsons.) The title of this project indicates its nature. Some work done with poultry suggests that the stimulus to egg production which results from the use of electric lights is not due entirely to the increased feed consumption in the longer day made possible by the lights, but is due in part to an indirect stimulus to the hen's reproductive system through the action of light on the pituitary gland. The question naturally arises: if this is true of hens, may not the light have a similar effect on cows.

The idea is being tried out in a small way to begin with. Two Guernsey cows of similar age, size, and productive ability, which freshened within a week or so of each other in November 1936, are being kept in adjacent box stalls so arranged that one of them is exposed only to such ordinary artificial light as is necessary to milk, feed, and care for her generally; while the other is exposed from dusk to dawn each night to the direct rays of a 1000-watt electric light. Their feed and care in all other respects are identical. They are not confined to the box stalls all the time but receive daily exercise in an adjacent yard. At the end of a month they will be reversed with respect to the light and these changes will be made at regular monthly intervals until the end of the barn-feeding season in April. In this way it is hoped to obtain a measure of the effect of the light, if there is any.

Studies in the Chemistry of Pasture Grass. (J. G. Archibald.) This project has been continued throughout the year using the two series of plots mentioned in the last report. Results from the second series will not be available until after the end of the 1937 growing season. Final conclusions on the first series await the completion of this seasons' analytical work which is now in progress. The following tentative conclusions are offered at this time:

(1) The conclusions published in the *Journal of Agricultural Research* for April 15, 1935, are in general confirmed by these later studies; viz., the high

rank of white Dutch clover, the high soluble ash and phosphorus content of orchard grass, the high calcium content of the bent grasses (Rhode Island bent and red top), the low rank of sheep fescue, and the rather low rank of Kentucky bluegrass.

(2) The application of a complete fertilizer lowered appreciably the dry matter content of the fresh grass, and the crude fiber and calcium in the dry matter; it materially increased the nitrogen in the dry matter and considerably increased the phosphorus. Smaller increases were noted in ether extract, soluble ash, and magnesium. These are average effects for all seven species studied. Individual species showed some variation in their response to the fertilizer treatment.

(3) There is a very significant positive correlation between moisture content of the fresh grass and content of nitrogen, soluble ash, calcium, and phosphorus in the dry matter of the grass. There is an even more significant negative correlation between moisture content and crude fiber content. It is concluded, therefore, that the amount of water in a grass is a good indication of the nutritive value of its dry matter.

The Vitamin Content of Certain Pasture Grasses. (W. S. Ritchie and J. G. Archibald.) This project was continued this year, samples of seven species of grass being assayed in the green state in June for vitamins A and D, and again in September for vitamin A. It is desired to repeat the work another season before publishing results.

Performance Prediction from Pedigrees. (V. A. Rice.) The materials for this study were published during 1935 and 1936 in the *Guernsey Breeders' Journal* in the form of comparisons in production between a bull's daughters and the dams of those daughters. Only those bulls with ten or more daughter-dam comparisons were included.

Intermediate indexes were computed for each of about 150 bulls. A study revealed about 35 bulls with complete pedigrees from the standpoint of production. These bulls were by sires with indexes and the grandsires also had indexes. The dams of these bulls had records, the two grandams had records, and the indexes were available on the sires of the two grandams. This material was put together into one composite pedigree for the 35 bulls.

The dam's record was averaged with her sire's index as the transmitting ability of the cow. The same procedure was followed also in the case of the two grandams. Six-tenths of the average of the sire's index and the dam's transmitting index was added to four-tenths of the average of the grandparents' transmitting indexes to yield a figure known as the pedigree index for these 35 bulls. This figure was 13,726 pounds of milk testing 5.09 percent. These bulls were bred to 610 cows whose 1,045 records averaged 12,859 pounds of milk testing 4.99 percent butterfat. The daughters should have produced, theoretically, half way between the average production of the dams and the pedigree index of the bulls. In other words, we should have expected them to produce 13,293 pounds of milk testing 5.04 percent. They actually produced 13,312 pounds of milk testing 5.09 percent. In terms of total energy (milk and fat combined) this is an error of about 0.7 percent.

The material was then treated individually for each of the 35 bulls, and the daughters missed expectations from 0.3 percent up to 16 percent, the general average discrepancy being 4.5 percent. The error for 27 out of the 35 bulls (77 percent) was 4 percent or less.

It appears therefore that the transmitting ability of bulls may be told fairly accurately by means of a pedigree index — said index being based on indexes of the sire, two grandsires, and the sires of the two grandams, together with records on the dam and the two grandams, as indicated above. Occasionally errors up to 15 or 20 percent will result, probably because the indexes were based on too small a proportion or on a selected number of a bull's daughters. Greater accuracy could probably be attained, if desired, by testing most of the daughters of a bull rather than a selected few.

The Relation of Birth Weight to Vitality and Growth Rate in Lambs. (Ralph W. Phillips.) A study of the birth weights and growth rates of 110 Shropshire lambs born in the college flock shows that the lambs which are heavier at birth have a better chance of surviving and are heavier at 4, 6, and 12 months than the lighter lambs. A summary of the data follows:

	Number	Percent Born Dead or Dead	Average Weight of Those in Flock at		
Birth Weight	of Lambs	Within 1 Mo.	4 Mo.	6 Mo.	12 Mo
8 lbs. and below	53	20.3	51.3	64.1	84.0
Over 8 lbs.	57	0.0	59.6	77.0	93.4

Only 50 percent of the lambs weighing 6 pounds and under survived to the age of one month.

The Development of the Testes and Scrotum of the Boar. (Ralph W. Phillips.) This project is reported in Bulletin 331 issued during the year.

The Speed of Travel of Ram Spermatozoa. (Ralph W. Phillips and Fred N. Andrews.) Ram spermatozoa were found to be able to cover a distance of 38.1 cm. *in vitro* suspended in Ringer's and Normal NaCl solutions at an average speed of 4.83 mm. per minute. The speed was greater at first and gradually decreased, the speed observed over each of six portions of the total distance being as follows: (1) 15.45, (2) 12.28, (3) 3.56, (4) 7.82, (5) 4.58, and (6) 2.28 mm. per minute. The above results were with normal spermatozoa. In trials with spermatozoa of which a large proportion were abnormal, the rate was slower and in some cases spermatozoa failed to cover the first portion of the distance.

In the genital tract of the ewe, spermatozoa were observed to cover a similar distance (37.2 cm.) at a rate as rapid as 12.4 mm. per minute.

A Survey of Graduate Study in Animal Husbandry. (Fred N. Andrews and Ralph W. Phillips.) Data from twenty-five state colleges and universities indicate the following distribution of subject matter upon which theses prepared by graduate students in these institutions have been based.

General Subject of Thesis	*M.A. and M.S. Degree*	*Ph.D. Degree*
Genetics	16	2
Breed History	6	1
Nutrition	133	9
Livestock Production	15	—
Physiology	10	2
Physiology of Reproduction	6	7
Meats	5	—
Miscellaneous or not stated	12	1
Totals	203	22

These data cover the period from 1920 to 1934 and indicate that more emphasis has been placed upon the general subject of nutrition than upon the general subjects of breeding, physiology, and meats.

Progeny Performance in Sheep. (C. H. Parsons, R. C. Foley, and J. C. Hillier.) A cooperative project with the U. S. D. A. was started in 1932, using the Southdown and Shropshire flocks of sheep, in order to determine the inherent capacity of specific families or strains of sheep for the utilization of feed and the production of meat and wool, and to improve them by a study of the manner in which they transmit these characters.

Accurate records are kept on all sheep, including lambing records, gains in weight, type scores made on all lambs at 140 days of age, and carcass grades of all sheep slaughtered. The wool on each sheep is graded and weighed yearly, and samples are analyzed by the Bureau of Animal Industry of the U. S. D. A. A specialist from the Bureau visits the college at least once each year to counsel with a committee from the college in grading the mutton and wool characteristics of the flock. This contact helps to keep the records uniform and comparable with similar records at other institutions.

Sufficient records have now accumulated to give valuable information on the offspring of the sires used in recent years. As an example, the body scores for four Southdown rams are given below. The figures are expressions of the difference between the average scores of lambs and their dams; a positive figure indicates improvement on the part of the offspring, and a negative figure indicates that they did not score as high as their dams. The scoring system employed was on the basis of 1 as perfection and grading down to 5 as the lowest possible score. For example: the ewes to which Ram A was bred had an average score for type of 1.25, the corresponding score for their lambs was 1.09, showing an improvement of .16 which is the figure given in the table.

Body Scores

	No. Offspring compared to dams	Type	Condition	Back	Rump	Leg	Head	Birth Weight Pounds
Ram A	5	+.16	0	+.50	—.33	+.16	+.08	
Ram B	5	+.13	—.60	—.07	—.20	—.20	+.27	+2.2
Ram C	11	—.41	—.81	—.33	+.11	—.37	—.07	+.4
Ram D	8	—.13	—.07	—.13	+.40	0	+.13	—2.28

It is felt that the type of ewes to which these rams were mated was unusually high and that as the level of the flock improves it becomes progressively more difficult for a ram to improve or even hold the type of the ewes. It should be noted that with the exception of the birth weights, all scores are the combined opinions of a scoring committee. It is doubtless the unconscious tendency of the scorers to grade more severely the nearer the level of the flock approaches perfection.

Similar information is now available on three Shropshire rams. In addition the weight, length, and characteristics of the wool for all sheep have been recorded and tabulated.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Microbiological Examination of Dried Foods. (J. A. Clague and James E. Fuller.) This work has been published by the senior author (*Food Research*, 1: 45–59, 1936). No further work is contemplated at this time.

Detection and Significance of Escherichia Coli in Commerical Fish and Fillets. (F. P. Griffiths and James E. Fuller.) This was a joint study with the U. S. Bureau of Fisheries. The results were published (*Amer. Jour. Pub. Health*, 26: 259–264, 1936). The study is not being continued.

The Influence of Bile and Bile Salts on Aerobacter Aerogenes. (James E. Fuller.) A preliminary statement has been published (Mass. Exp. Sta. Bul. 327, p. 21, 1936) concerning the influence of one percent concentrations of ox bile, sodium glycocholate, and sodium taurocholate on the biochemical reactions of *Aerobacter aerogenes*. It was thought that some variations in these reactions might be induced by cultivation of various strains of the organism in the presence of bile and bile salts. No variations were observed after five months' cultivation of the organisms, with weekly transfers to fresh media. Higher concentrations of the bile and bile salts are now being employed. To date, after two months of weekly transfers, the cultures continue to exhibit the same biochemical reactions as at the beginning of the experiment. Indications are that under the conditions of the experiment bile and bile salts do not induce variations in *Aerobacter aerogenes* cultures.

Lipolytic Activity of Gram-Negative Intestinal Bacteria. (James E. Fuller and E. W. Harvey.) This study was planned to investigate the extent of lipolytic activity among Gram-negative bacteria common to the human intestinal tract in health and in disease, and to determine whether or not there was any correlation between the lipolytic activity of the bacteria employed and their ability to digest proteins and carbohydrates. Lipolytic activity was not general among the Escherichia or Aerobacter cultures employed, but 13 of 25 intermediates of the group studied possessed active lipolytic power. No lipolysis was observed among the strains of Salmonella, Eberthella, or Shigella studied. There did not appear to be any relation between lipolytic ability and either proteolysis or carbohydrate utilization.

Influence of Added Iodine on the Bacterial Flora of Milk. (James E. Fuller and George S. Congdon.) Iodine was employed in the form of tincture, Lugol's solution, and colloidal iodine. The quantity of each was varied to determine the amount of iodine required to inhibit bacterial growth in milk. More iodine was required to inhibit bacterial growth in milk of high initial bacteria counts than in milk with low initial counts. Tincture was found to be more effective than Lugol's solution. Less work has been done with the colloidal iodine, but indications are that it will approximate the tincture in inhibiting power.

Effect of Raw, Pasteurized, and Iodized Milk on the Fecal Flora of White Rats. (Wm. B. Esselen and James E. Fuller.) This study was undertaken to investigate a claim that pasteurized milk has a tendency to induce intestinal putrefaction while raw milk does not, and that the addition of iodine is more effective than pasteurization as a means of controlling the bacterial growth in milk. Four series of white rats were maintained on the following diets: Basal diet plus raw milk, basal diet plus pasteurized milk, basal diet plus raw milk with added iodine, and basal diet plus pasteurized milk with added iodine. In one experiment the basal diet was high in carbohydrate (cereal), and in a second experiment the basal diet was high in protein (hamburg steak). To date there have been no indications that either pasteurized or raw milk will produce a putrefactive flora in the intestinal tract of the rats, nor did the added iodine appear to control putrefactive flora which did occur. There was considerable individual variation in the intestinal flora of the rats studied.

A Comparative Study of Certain Presumptive Media for Testing Raw Waters. (Ralph L. France.) The results of this study have been published in the *Journal of the American Water Works Association*, Vol. 28, No. 6, June, 1936.

The Indol Tolerance of Certain Strains of the Coli-Aerogenes Group. (Ralph L. France.) The results of this study have been published in the *Journal of Bacteriology*, Vol. 32, No. 2, August, 1936.

Studies on Acid Production by the Coli-Aerogenes Group. (Ralph L. France.) An abstract of the preliminary report of this study has been published in the *Journal of Bacteriology* Vol. 32, No. 1, July, 1936. Work on this study is being continued.

The Tolerance of the Coli-Aerogenes Group for Brilliant Green. (Ralph L. France.) Evidence obtained to date shows that the Aerobacter group has a considerably greater tolerance for brilliant green than the Escherichia group. Work will be continued on this project using a large number of strains of organisms and varying amounts of inoculum. Also it is planned to study the action of bile on the tolerance of this group for brilliant green.

The Action of the Coli-Aerogenes Group on Erythrosin. (Ralph L. France and James E. Fuller.) A preliminary report of this study has been made (Mass. Exp. Sta. Bul. 327, p. 21, 1936). A study of the action of the intermediate members of the Coli-Aerogenes group shows that some strains precipitated the dye while others failed to do so. These reactions checked very closely with the methyl-red reactions of the various strains. However, a failure to obtain consistent results with certain strains on repeated tests indicates a need of further study of these strains.

A Study of the Eijkman Test. (Ralph L. France.) A preliminary report of this study has been made (Mass. Exp. Sta. Bul. 327, p. 21, 1936). Strains of *Aerobacter aerogenes* and the intermediate group failed to produce acid and gas in the Eijkman broth at 46° C. Some strains produced acid at 45° C. but none produced gas. Further studies are being carried on with strains of the Coli-Aerogenes group isolated from fresh feces.

Laboratory Service. (Ralph L. France.) Following is a list of the numbers and types of examinations made in the laboratory during the past year:

Milk (bacteria counts)	1,289
Ice Cream (bacteria counts)	148
Water	85
Miscellaneous:	
*Butter Fat (Milk)	228
*Total Solids (Milk)	28
Throat Swabs	24
Total	1,802

*Analysis made by Feed Control Laboratory

Flood Relief. (The Department.) Following the disastrous flooding of the Connecticut River Valley in March of 1936, an emergency service was established to aid in rehabilitation. Three men were sent into the flooded areas to investigate sanitary conditions and to give advice and service in the elimination or abatement of health hazards. Particular attention was given to water supplies. Private supplies showing evidence of pollution were sterilized under the supervision of our field staff and samples were retested in the laboratory until evidence of pollution had disappeared. Assistance was also given to the State Department of Health in handling water samples taken from municipal supplies. During the emergency 220 bacteriological analyses were made in our laboratory.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.) Since the previous annual report two more generations (F_3 and F_4) of tomato hybrids have been grown for further selections for resistance to Cladosporium leaf mold and for quality. Some seed samples of these tomatoes have been distributed to other experiment station workers in the United States and Canada for trial and report.

As a between-crop treatment to cleanse the greenhouse interior of fungous spores, the burning of sulfur (4 lbs. to 10,000 cu. ft.) was found to be entirely adequate. Plant life and most insects succumbed to this dosage. Zinc oxide is apparently the only white paint pigment to react with sulfur dioxide to produce a soluble plant poison. The proportion of this pigment which must be present in prepared paint in order to produce sufficient zinc sulfate to cause plant injury remains to be determined. Zinc-coated wires used to trellis plants are also a source of the injurious sulfate. Tinned or stainless steel wires do not react and are recommended as substitutes. Naphthalene vapor and hydrocyanic acid gas, which are sometimes used to eradicate insects between crops, do not react with paint and metal; but in tests at excessively high dosages both lacked fungicidal value when spores of *Cladosporium fulvum* Cke. were used as an index.

This fungus is specified in the literature as the cause of a green mold rot of tomato fruits from California and Mexico. Cultural and physiological characters of the fungus from rotted California tomatoes arriving at the Boston Terminal Market revealed distinct contrasts to the prevalent Cladosporium leaf mold fungus on tomato foliage under glass.

It was determined that *Cladosporium fulvum* Cke. is the cause of a rather prevalent asthma among greenhouse tomato workers in the United States and Canada. According to the writer's experience desensitivity may readily be accomplished by proper treatment with extracts of the fungus.

Causes and Control of Decay of Winter Squash in Storage. (E. F. Guba and C. J. Gilgut, Waltham.) A survey of squash storages in the season of 1935–36 revealed rather wide differences and opinions relative to proper storage temperatures. The merit of low storage temperatures is supported by laboratory cultural studies in which the growth of organisms producing squash rot was completely inhibited at 40° F. and lower. The maintenance of such temperatures in squash storages, however, requires better construction and insulation of the building, adequate means of ventilation, and more accurate and reliable control over heating.

The disinfection of the squash in storage after harvest by fumigating with formaldehyde offers an attractive substitute for the obnoxious formaldehyde dip treatment. A periodic disinfection of the squash in storage with formaldehyde gas suggests a practical means of controlling decay. Details and dosages will be given further study.

As the result of extensive artificial inoculation of squash in the field and after harvest with decay organisms from pure culture, it is apparent that (1) injuries predispose the squash to infection; (2) infection becomes increasingly successful at points of injury as the life of the squash cells required to produce callus is lost; (3) cessation of callus growth is correlated with or followed by vital chemical changes which render the squash a favorable nutrient medium for the growth of decay organisms; (4) a distinct correlation exists between size (maturity) and decay.

Field applications of Bordeaux and copper–lime dust were made on two distinct areas of squash in the field. One area was left untreated. No contrasts were apparent. Such applications were not considered practical beyond midsummer.

At harvest the following treatments were compared: (1) formaldehyde dip, (2) pre-storage in the field under vines, (3) careful handling, (4) cutting the stems short, (5) rough handling, (6) fumigation with formaldehyde. The results are not yet available.

Miscellaneous Tests and Experiments. (C. J. Gilgut and E. F. Guba, Waltham.) Frequently, in the field of plant disease control, results obtained by investigators in other localities appear to be applicable to use in this State. Often, however, it seems desirable to test such results under our own conditions before recommending them to growers. The following tests in part were carried on for that purpose.

1. *Vegetable Seed Treatments.* Dry chemical seed treatments for controlling damping-off were limited to red copper oxide, zinc oxide, Semesan, and Semesan Jr. The results, collated with the work of previous years, are summarized in the following recommendations.

Either red copper oxide or zinc oxide		Either red copper oxide or Semesan	Either Semesan or zinc oxide	Either Semesan or Semesan Jr.
Copper oxide preferred	Zinc oxide perferred	Copper oxide preferred	Semesan preferred	
Lettuce	Radish	Beets	Beans	Corn
Pepper	Turnip		Onions	
Carrot	Cucumber		Peas	
Eggplant	Parsnip		Cabbage	
Tomato	Spinach		Cauliflower	
Squash	Lima beans			

2. *Tests of Fungicides on Field Tomatoes.* Spray tests were made of various proprietary and homemade fungicides on tomatoes to determine the effect on foliage, yield, and disease control. Ten applications were made at 7 to 10 day intervals beginning on June 23 and continuing to September 2.

Materials used, percentage content of metallic copper, and strength of application were, Market Garden Copper (11 percent) 1 part in 128 parts of water;

Burgundy (12½ percent) 2-3-50; Bordeaux (25 percent) 4-4-50; Copper Hydro "40" (26 percent) 4-50; K K Copper Compound (25 percent), a copper oxychloride preparation, 4-50; Oxo-Bordeaux (12½ percent) 8-50; Coposil (18 percent) 3-50; Sherwin-Williams Basi-Cop (52 percent) 2-50; and Wettable Sulfur 4-50. Sprays were applied with a wheelbarrow sprayer.

Absence of fungous diseases rendered comparison of fungicidal values impossible. Slight burning of the foliage was caused by Bordeaux and severe burning by Burgundy. The most significant feature of the test was a striking reduction in yield resulting from use of these two sprays.

3. Eggplant Wilt (*Verticillium*). It has been established that treating eggplant seed in hot water at 120°–125° F. for 30 minutes kills the wilt fungus without reducing the viability of the seed. Plants grown from seed so treated were distributed to six farms in Massachusetts. Examination of these plantings on August 25 showed infection ranging from 50 to 100 percent on five farms, and 2.15 percent on one farm.

These observations support the view that the causal fungus is present rather generally in the soil. This fact renders the hot-water seed treatment of no apparent value; hence, there seems no justification for recommending its use. In the one instance where the seed was grown on abandoned sod, the planting was practically free of wilt. Apparently benefit from seed treatment can be expected only in cases where eggplant is to be grown on fresh or abandoned sod land and the fungus is virtually absent or inhibited by unfavorable soil reaction.

4. Spraying Greenhouse Cucumbers for Control of Powdery Mildew. Cucumbers were sprayed in two greenhouses with the following fungicides: Bordeaux 1-1-50, Bordow 2–50, Corona Copper Carbonate (50 percent) 1-50, Corona Copper Carbonate (18 percent) 2-50 and 3-50, Hammond's Copper Solution 1-150 and 1-200, Mike-Sulfur 2-50, Potassium Sulfide 1-50, and Sherwin-Williams Basi-Cop (52 percent) 1-50. To each 50 gallons of spray was added ½ pint of Penetrol.

All of the treatments controlled powdery mildew. None caused sufficient stain on the cucumbers to be objectionable.

Sulfur provided slightly longer protection than copper, but in all cases the renewal of the sprays within 10 days was necessary to maintain control.

5. Trials of So-Called Rust-Resistant Beans. Fifteen bean hybrids selected for resistance to rust were obtained from the Virginia Experiment Station and two from the United States Department of Agriculture. These were grown to observe plant characters and reaction to bean rust caused by *Uromyces phaseoli* (Pers.) Wint. var. *typica* Arth.

Eleven of the strains from Virginia were found to be very susceptible to rust. Four hybrids, 32-C-3, 32-C-4-2, 14-A-32-1935, and 5-A-32-S-33 were only slightly susceptible. None yielded beans. The two strains obtained from the United States Department of Agriculture were found to rust heavily and yielded moderately. None of the strains tested was found to be sufficiently resistant or productive to warrant recommendation here.

Carnation Blight, Alternaria Dianthi S. & H. (E. F. Guba, Waltham.) Two field tests to demonstrate the control of this disease according to the author's recommendations proved highly gratifying to members of the New England Carnation Growers Association and other carnation growers.

A mixture of Bordeaux 5–5–50, calcium arsenate 1 lb., and Penetrol (spreader) ½ pint, was employed as the fungicide. As a severe test of the fungicide, the plots were protected throughout the outdoor growing season beginning with the first application on June 8, and ending with the last on August 24 at the Field Station, Waltham, and on September 21 at Rice's in Lexington, making a total of 10 and 13 applications respectively. The significant results of these tests are as follows:

Plots	Number of infections per 1,000 flowering stems		Average number of harvested flowering stems per plant	
	Sprayed	Not sprayed	Sprayed	Not sprayed
Waltham Field Station	96	1,630	3.48	4.73
Rice — Lexington	51	2,556	1.65	1.39

Aside from the good control obtained, the sprayed plants showed better color and growth according to the judgment of the Research Committee of the New England Carnation Growers Association. The tests gave a previously divided sentiment convincing evidence of the virtue and safety of the treatment recommended.

This project is terminated, but the preparation of manuscript has been delayed by other work.

Diseases of Herbaceous Ornamental Plants Caused by Soil-Infesting Fungi. (W. L. Doran.) Seedlings do not often damp-off in washed sand unless the sand is later contaminated, as by inoculation. In five different sands, however, even with potassium nitrate added as nutrient, seedlings of most species used in this work usually grew less well than in soils. Absence of damping-off is not enough if seedlings meanwhile grow but poorly; and sands were not very satisfactory media for seedage of species, the seedlings of which are naturally small and slow to grow in any medium.

In other experiments, seeds were sowed in other media including sand and sphagnum (half and half) and sand and peat moss (half and half), with the object of determining the effect not only on germination and damping-off but also, and especially, on growth of seedlings. Growth was better in sand and sphagnum or in sand and peat moss than in sand, and was often as good as in soil, provided that potassium nitrate was added in all cases.

Growth of seedlings of some species was better in sand and sphagnum than in sand and peat moss. This may be, at least partly, the effect of soil reaction. The addition of peat moss to sand increased acidity more than did sphagnum; for the latter, added to sand, lowered pH values very little or not at all.

There was sometimes more damping-off in these mixtures, especially in sand and peat moss, than in sand alone; but in them, as in sand, it was usually trifling as compared with its severity in soil.

Considering both damping-off and growth of small, slow-growing seedlings, no medium for seedage gave better results than did sand and sphagnum.

If soil is used, as it often must be, then soil disinfection is in order, and for this purpose formaldehyde dust has largely replaced the less convenient liquid formaldehyde. On the basis of work here reported upon, acetic acid dust, instead of acetic acid in water, may be similarly used with good results and no less convenience than formaldehyde dust.

Acetic acid dusts containing 24 to 25 percent acetic acid have been made by absorbing 1 pint of 80 percent acetic acid in 2.5 pounds of powdered wood charcoal, and these were well mixed with moderately dry soils, naturally infested or artificially inoculated, using 1.5 oz. of the dust per square foot of soil (3 inches deep). Seeds were sowed immediately and soils were then well watered. Good, although not always complete, control of damping-off was thus obtained.

Growth of most species was generally either unaffected or, in some cases, improved, as when Rhizoctonia in untreated soils interfered with growth of seedlings. For the present, it is considered safer, however, to delay seeding until at least one day after soil treatment with acetic acid.

Neither acetic acid nor formaldehyde is always at hand when needed by growers and plantsmen, and this is one principal reason why seeds are often sowed without any protection against soil fungi, for convenience or the lack of it is of course an important consideration in practice. Cider vinegar, as usually sold, contains 4 to 5 percent acetic acid and there are few substances more readily available or more generally at hand. An investigation of its use as a soil disinfectant was therefore begun.

Five undiluted cider vinegars,[1] containing about 4 to 5 percent acetic acid, were mixed with moderately dry and sandy soils, naturally infested or inoculated, the latter being a more severe test. Seeds were sowed immediately or within 24 hours and soils were then well watered. Vinegar 200, 237 (about ½ pint), or 250 cc.[2] usually gave satisfactory but not always complete control of damping-off and it was generally without harmful effect on germination or early growth of most species. In these quantities, it cannot be safely applied to living plants, however.

Potassium permanganate is occasionally referred to as being a soil disinfectant, but in these experiments it did not prevent damping-off of seedlings when added in amounts up to 30 gms.

Seeds often germinated better in soil to which salicylic acid, 3 to 5 gms., had been applied than in soil without this treatment; but there was no less post-germination damping-off with it than without it.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modifications of Environment. (W. L. Doran.) The time or date of taking cuttings apparently affected their rooting as much as the presence or absence of soil fungi or any other one factor. Fairly hard cuttings of several species lived and struck root as well in rooting media (sand or sand and peat moss) inoculated with species of Pythium or Rhizoctonia as in the absence of these fungi. Cuttings taken earlier or when softer were more susceptible to infection, but when taken too late they struck root more slowly and less well, that is, in smaller percentages. Dates of taking cuttings which rooted well are being recorded, especially in the case of species which are sometimes considered rather difficult to propagate by cuttings; and some of the information thus secured should be useful to propagators.

In studying the effects of several rooting media, it was observed that sand is a better medium for the rooting of hardwood cuttings of *Daphne Cneorum* than is any mixture of peat moss with sand.

Acetic acid dusts, made and used as described in connection with the preceding project, were injurious to cuttings inserted within 24 hours after treatment of rooting media, although they were safe with the seeds of these same plants. Acetic acid dust and formaldehyde, both of which are soon lost from soil, did not completely protect slowly germinating seeds of woody plants against damping-off.

Watering of media with much-diluted vinegar did not affect the rooting of cuttings of most species; but the following, which were among the least woody of those used (on July 1), struck root decidedly better in sand and peat moss with these treatments than without them: *Cytisus purpureus* and *Genista tinctoria* watered only with vinegar 8cc. diluted to 4000 cc. with water, and *Artemisia Abrotanum* and *Indigofera decora* watered only with vinegar 16 cc. similarly diluted.

---

[1] Summarized results of this work have been reported in a previous paper (Science 84: 2177: 273–284. 1936.)

[2] In the report on this and the following project, numbers of cc., gms., or oz. are, except as otherwise indicated, those applied per square foot of soil surface.

Cuttings of several species were allowed to stand for some hours with their bases in solutions of indoleacetic acid or indolebutyric acid, following which treatments they were inserted in sand. More species were unaffected than were benefited, but the rooting of some was hastened and otherwise improved by the treatments, as follows:

Species	Date	Grams in 1,000 cc. of water		Number of hours of treatment
		Indoleacetic acid	Indolebutyric acid	
Abelia grandiflora	Aug. 20	—	0.025	65
Caryopteris incana	July 31	0.050	—	41
Chamaecyparis sp.	Aug. 20	—	0.025	65
Chamaecyparis pisifera var. *plumosa*	Aug. 20	0.100	—	22
Chamaecyparis pisifera var. *squarrosa*	Oct. 17	—	0.100	24
Coronilla Emerus	Oct. 17	0.100	—	23
Corylopsis spicata	Aug. 20	—	0.025	48
Dorycnium hirsutum	Oct. 16	—	0.100	22
Lespedeza formosa	Oct. 16	0.100	—	22
Styrax Obassia	July 31	0.025	—	65

In some cases these treatments not only improved rooting, but also apparently prolonged life of cuttings. Thus, when 36 percent of the treated cuttings of *Lespedeza formosa* had rooted and 96 percent were living, only 50 percent of the untreated cuttings of this species were living and none of them had then struck root.

These treatments are not inexpensive and it is important therefore to learn not only for what species they are altogether unnecessary, but also for what species they are most beneficial. In this work, and with some exceptions, the cuttings most benefited were the softer wooded and those from which roots develop along the whole length of the buried stem.

Phenylacetic acid, as used, was without effect on the rooting of hardwood cuttings.

Rooting of cuttings was improved more by their treatment with indoleacetic or indolebutyric acids than by the treatment of rooting media with potassium permanganate, and the effect of the latter was not influenced by inoculation of the medium.

A severe disease of the above-ground parts of thyme, several varieties of *Thymus Serpyllum* L., was observed in gardens. A strain of *Rhizoctonia solani* was isolated and its pathogenicity established by inoculation. Infection is common in rainy weather in early summer, and the otherwise attractive mats made by this fine ground cover become unsightly.

Diseases of Trees in Massachusetts. (M. A. McKenzie and A. Vincent Osmun.) Field and laboratory investigations to determine the occurrence and significance of shade tree diseases in Massachusetts, initiated in the summer of 1935, were carried on during the past year. The principal objective of the program was to determine whether the so-called Dutch elm disease, caused by the fungus *Ceratostomella ulmi* (Swartz) Buisman, was present in the State.

As the name implies, the Dutch elm disease was first observed in the Netherlands in 1919 and thousands of elms there and in other European countries have been killed by the disease. Reports from Europe indicate that the disease exists throughout the extensive range of climatic and soil conditions included in the following countries: Netherlands, France, Italy, Austria, Belgium, Switzerland, Germany, Poland, Czechoslovakia, Balkan States, and Great Britain. In the last-mentioned country, the disease is widely distributed. Recent reports indicate that diseased trees are found within thirty miles of the Scottish border.

In America, from 1930 to 1932, the known cases of the disease were limited to less than a dozen trees in Ohio. During the last three years, however, more than 21,780 cases of the Dutch elm disease have been found in New Jersey, New York, and Connecticut. Isolated cases have been found in Virginia, Maryland, and Indiana. Destruction of all affected elm trees is the aim of the present control program in the United States.

Up to the present writing (December 1936), the disease has not been found in Massachusetts. Nevertheless, the threat of the disease here is imminent since the malady is known to occur within forty-five miles of the southern border of the State, in Connecticut and New York. Also worthy of attention is the fact that the earliest known American infestation of the principal carrier-insect of the disease, the smaller European bark beetle (*Scolytus multistriatus* Marsh), was discovered in Massachusetts in 1909.

Since the organization of the shade tree disease survey in June 1935, approximately 5,000 specimens have been studied in the laboratory. During 1936, the specimens were collected by four field men from the laboratory, scouts from the State Department of Agriculture, and citizens throughout the Commonwealth. This year, sixty-two diseases of thirty-one hosts were reported, including thirteen diseases of elm.

A detailed study has been made of the State-wide distribution of elm wilts associated with species of Cephalosporium and Verticillium. The occurrence of either or both organisms in 123 cities and towns is shown.

Experiments on potted elms of several species have been conducted in the greenhouse with the vascular fungus parasites of elm known to be present in Massachusetts.

In 1935, considerable assistance was rendered the survey by the organization of an F. E. R. A. project. Since September 1936, a W. P. A. project has helped in the laboratory work.

Moist Mats for Clay Pots. (L. H. Jones.) A clay pot should always be used on a moist surface. The root system in such containers is next to the wall of the pot, and should the pot wall become dry, a drought hazard would exist. Capillary moisture, pulled up from below the pot, is sufficient for the protection of the roots. This is easily accomplished in greenhouses where moist bench surfaces of soil, cinders, and sand are practical, but in homes and offices a substitute is necessary. The testing of various materials has resulted in the development of a mat which will absorb water and transmit it to the clay pot resting on the surface of the mat. The mat is featured by recesses that not only provide reservoirs for free water, but also serve as drains to lead away any free water about the base of the flower pot.

Mats of wood pulp, wood fiber, and leather waste are suitable. Metal forms filled with cotton or woolen cloth, sphagnum moss, peat moss, and absorbent cotton may also be used. Ceramic materials have been tested, but none were as efficient as fibrous materials. Sponge rubber supplied free water which was detrimental to the plant as it caused a waterlogged condition in the soil.

The Water-Supplying Power of Soils. (L. H. Jones.) A relatively rapid method of determining the water-supplying power of a soil at different percentages of its water-holding capacity shows promise of being fairly accurate and practical. Measuring in seconds the time it takes for moisture to strike through blotting paper held to the soil by a glass weight shows increased time with soils of high water-holding capacity and decreased time with soils having a low wilting coefficient.

Selocide as a Plant Stimulant. (P. F. Bobula and L. H. Jones.) A spray material commercially called Selocide and used to control red spider has produced on roses a general increase in height of plant, length and breadth of leaves, and thickness of stem. Tests with tomato plants indicate that the stimulation is effected by volatile materials in the spray which find access to the plant through the atmosphere.

Effect of Soil Temperature on a Chlorosis of Gardenia. (L. H. Jones.) Observations of gardenia plants in several environments indicated that, when all other factors were equal, a low soil temperature induced an intervenal chlorosis of the top leaves and that longer exposures to low soil temperatures accentuated the condition to the point where the leaves were entirely yellow and often almost white. Raising the soil temperature caused a reappearance of green which was first evident in the new-forming leaves and gradually worked down the stem to the older leaves.

Plants grown in soil temperatures starting at 8° C. and increasing in 2° steps through 32° showed yellowing induced at 18° and less, with no signs of yellowing at 22° and above.

The size of the gardenia leaves was definitely tied up with soil temperature and not with air temperature.

DEPARTMENT OF CHEMISTRY

W. S. Ritchie in Charge

Cooperative Analytical Service. (The Department.) Cooperative work with the several departments has been continued. The analytical service to the investigators at the Waltham Field Station has been the major and most important activity. Determinations for iron, manganese, copper, phosphorus, and soluble and insoluble ash were made in the study of the cause and prevention of chlorosis in gardenias.

Testing Analytical Methods. (The Department.) The work aiming at the improvement of the methods for determining iron, copper, and iodine has been continued. Considerable time was spent in collaborating with the Associate Referee of the A.O.A.C. in charge of developing suitable methods for determining copper in foods.

The obligation of investigating and attempting improvement in the methods for zinc (as associate referee) in foods was assumed. A survey of the methods for determining zinc has been made and work begun, but no collaborative work has been attempted as yet.

The effort to improve the methods for determining iodine in foodstuffs has been continued and a method developed which is believed to be satisfactory. The method consists of the ignition of the sample in a semi-closed silica tube in the presence of calcium oxide, passing the products of combustion through heated nickel oxide as a catalyst thereby completing the burning, particularly of the "tarry" products. The gases and the iodine are absorbed in appropriate solutions which are later evaporated to dryness and extracted with alcohol. The alcohol extract is evaporated to dryness and the iodine determined by titration with thiosulfate in the usual manner. The apparent improvements consist in the manner in which the combustion is accomplished and the use of nickel oxide as a catalyst rather than the usual platinum.

The Iron, Copper, Manganese, and Iodine Content of Fruits and Vegetables used as Human Foods. (E. B. Holland, C. P. Jones, and W. S. Ritchie.) Since the inauguration of the project some 126 samples of fruits and vegetables including the skins or tops of some products have been analyzed. This comprises the determination of the various food groups — protein, fat, nitrogen-free extract, fiber, acid soluble ash, and insoluble ash, together with the iron, copper, manganese, and phosphorus content. Analysis of one sample each of milk, codfish and cottonseed meal has been completed and work on eleven samples of cattle feeds, grain, and roughages is under way.

In addition, eleven new samples of fruits and vegetables, seventeen samples of cereals and cereal products, and two samples of extracted soybean meal have been secured on the open market for analysis.

The analyses of these samples as well as those obtained in the following project are virtually complete and should be available for publication in the coming year.

Absorption by Food Plants of Chemical Elements of Importance in Human Physiology and Nutrition. (E. B. Holland, W. S. Ritchie, and W. S. Eisenmenger.) Beets, carrots, onions, lettuce, spinach, and swiss chard were raised in lysimeter tanks under special fertilization during the past season to determine the ability of these crops to assimilate iron, copper, manganese, and iodine. Forty-two samples were secured and will be analyzed under the preceding project. The analysis of these samples will soon be completed and results available for publication.

The Carbohydrates in Kentucky Bluegrass. (E. Bennett.) The procedures of 1935 were continued in the main except that samples were taken early in the morning (8:00 to 9:00 a.m.) rather than late in the afternoon (4:00 to 5:00 p.m.). This was done in the hope of effecting a shift in the carbohydrate equilibrium.

In 1935 all carbohydrates increased in percentage with maturity of the grass, except those soluble in 80 percent alcohol. This group represented by total reducing sugars and sucrose decreased in percentage. The most obvious interpretation of such an equilibrium would be that the more complex groups increased at the expense of the simple sugars. This is tenable but is probably more apparent than real.

In 1936 all carbohydrates determined increased in percentage with maturity. The alcohol-soluble fraction increased until the "blossom stage," then decreased, while those more complex continued to increase as would be expected.

Hemicelluloses of Tobacco Stalks. (E. Bennett.) Tobacco stalks while valuable as a fertilizer are of interest from the standpoint of waste utilization.

Consequently the content of protein, lignin, cellulose, and hemicellulose were determined. The total nitrogen was found to be approximately 3.50 percent of which 42 percent was ammoniacal. The lignin content was about 12 percent. (The content of cellulose and hemicellulose explain the reason why the stalks are easily decomposed.) The cellulose and hemicellulose were present to the extent of approximately 36 and 19 percent respectively. The hemicellulose, a polyuronide, was isolated and studied. Xylose proved to be the chief sugar obtained on hydrolysis. The stalks are now being investigated as a commercial source of this carbohydrate.

The Bacteriostatic Effect of Lignin. (E. Bennett.) Lignin is looked upon as being not only very resistant to bacterial action but also as practically indigestible. Isolated lignin has been known to produce bacteriostatic conditions when added to decomposing material. With these facts in mind the question arose as to whether or not the intestinal flora of small animals could be modified by an abnormally high lignin diet. Lignin was obtained from shavings, purified, and fed to guinea pigs. The procedure unfortunately had to be curtailed for the time, but it is hoped that this may be continued after the first of the year.

The Vitamin A Content of Certain Pasture Grasses. (W. S. Ritchie and J. G. Archibald. Cooperative with Animal Husbandry.) Samples of the grasses used for the vitamin assay in 1935 were those taken and prepared for chemical analysis. During the growing season of 1936 samples of sheep fescue, Rhode Island bent, bluegrass, red top, and timothy were taken and fed green to the vitamin A deficient animals. These grasses were grown on fertilized and unfertilized plots. However, no comparison should be made until results of the next season are available since duplicate samples were not always available.

The Nutritive Value of Fishery Products as Human and Animal Food. (W. S. Ritchie, G. C. Crooks, and C. R. Fellers. Cooperative with Horticultural Manufactures.) Under this project a rather complete study has been made of the chemical composition and nutritive value of haddock as affected by commercial processing. The samples were obtained through the cooperation of the Birdseye Frosted Foods Sales Corporation and represented four different conditions: fish frozen at sea with dry ice immediately after catching, the whole fish frozen at the pier, and commercial fillets prepared by the so-called quick and slow methods of freezing.

Nutritional studies made over the course of about fourteen months to determine the value of these samples for growth, reproduction, and lactation of the albino rat indicated that the fish frozen by any of the four methods was an adequate source of protein. The animals receiving the commercial fillets frozen by the quick method made a somewhat better record, especially in reproduction and lactation. An additional study is being made to determine the effect of long storage on the nutritional value of quick-frozen fillets. In this work, fillets frozen by the quick method and held at a temperature of −5° C. for over a year are being used as the source of protein in an otherwise normal diet.

Determinations for moisture, ammonia, total nitrogen, ether extract, and total ash were made on the monthly samples. The results indicated that the method of freezing did not in any way affect the chemical composition of the muscle.

Representative samples were also analyzed for the inorganic constituents, copper, iron, manganese, and phosphorus. These likewise were not materially affected although the manganese seemed to show a seasonal variation. Samples were dried and are being held for further inorganic analysis.

The separation of the nitrogen fractions soluble in a 10 percent sodium chloride solution indicated that although there was no appreciable difference between the commercial fillets, regardless of the method of freezing, there was a decrease in the amount of soluble nitrogen during storage. While there was no increase in the amount of ammonia nitrogen in any of the samples during storage at low temperatures, a very definite correlation is apparent between the amount of ammonia and the length of time that either fresh or defrosted samples were held at temperatures above freezing.

Assays for vitamins A and D indicated that, although haddock muscle is not an important source of these nutritional constituents, both are present in measurable amounts and are apparently not affected by freezing.

Chemical Changes in Cooking of Vegetables. (M. E. Freeman.) This study was undertaken to determine, if possible, the fate of certain constituents of vegetables during cooking processes. Preliminary trials indicated that the published analytical methods for determination of sugars, starch, pectic fractions, and hemicelluloses do not, in all cases, allow direct application to the material at hand. Modifications have been devised that allow the determination of pectic fractions in the presence of large amounts of starch. Extraction periods may be shortened if samples are finely ground. In preliminary trials ammonium oxalate seemed preferable to other agents for pectic extraction. In the determination of pentoses by the steam distillation and bromine titration method, the rubber connections in the steam line were found to cause error. All glass apparatus is recommended.

The Nutritive Value of Rare Elements in Plant Nutrition. (H. R. DeRose, W. S. Eisenmenger, and W. S. Ritchie. Cooperative with Agronomy.) It is becoming more and more apparent that very small amounts of the so-called rarer elements play an important part in the nutrition of plants. Because of their peculiar ability to act as anions and cations, chromium and molybdenum seemed to offer a fertile field for study. The latter had to be discarded and zinc and copper were added to chromium because of certain connections to other local projects.

Tomato and buckwheat plants, both rapid growers, are being grown in sand cultures with Knop's nutrient solution of $Ca(NO_3)_2$, K_2HPO_4, $MgSO_4$ and $FeCl_3$ to which are added dilute solutions of definite concentrations of the salts of the metals in question. All salts used in the nutrient solution and in the test solutions have been carefully recrystallized. The sand used has been washed with acid, tap water, and distilled water and then dried at 100° C. to insure the absence of interfering substances. The following concentrations are being used: Copper .05, .15, .5, 1, 5 ppm; Zinc .05, .10, 10, 30 ppm. Concentrations of chromium will be used in the initial studies as follows: 1, 10, 20, 30, 40, 50, 60 ppm.

This project has not been in operation long enough to justify the presentation of results.

THE CRANBERRY STATION

East Wareham, Massachusetts

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Half-winged Geometer. Moths of the species referred to as the "red-spotted spanworm" on page 37 of Massachusetts Agricultural Experiment Station Bulletin 239 were reared and found to be the half-winged geometer, *Phigalia titea* (Cramer). The male moths emerged during the last decade in March and the first week in April and the females mostly in the second week of April. The moths are said to be found in nature till early May. They are gray. The females are wingless. Some of the males have well-developed wings but many have only vestigial ones. The wing expanse of the winged males ranges from an inch to an inch and three-fifths.

The worms of this insect are often rather plentiful on dry cranberry bogs in late May and the first half of June, though no really destructive outbreak of them there has ever been noted. They also attack apple, beech, birch, blackberry, blueberry, cherry, elm, linden, maple, and rose. When full-grown, they are somewhat over an inch long, the head being whitish with many black spots; the body gray with black lines along the back and sides and with a row of conspicuous, irregularly shaped, much broken, light reddish-yellow spots along each side and smaller yellow spots along the back; the back and sides with scattered black tubercles of varying size, each tubercle bearing a single rather long hair.

This species passes the late summer, fall, and winter as a pupa. It ranges west into Minnesota, south into Virginia, and north probably into Canada.

Grape Anomala (*Anomala errans* Fab.). The first injury ever observed as having been done to a cranberry bog by this insect occurred in Sharon, Mass., and was described in the annual report of the cranberry station for 1934[1]. The grubs were found in abundance in April 1936, in the turf of the Kelley and Thomas bog near South Middleboro. They had injured fully an acre of the bog more or less severely. This bog has many grape vines near it as did the one in Sharon.

Fire Beetle (*Cryptocephalus incertus* Oliv.). The first recorded injury to a cranberry bog by this insect was described in the report of the cranberry station for 1915[2]. The writer never saw it so widely abundant on Cape Cod bogs as in 1936. Its feeding browned noticeably five acres of a bog in Lakeville. A spray of 6 pounds of lead arsenate in 100 gallons of water, applied at the rate of 250 gallons an acre early in September, killed 99 percent of the beetles present; and 10 pounds of derris powder (4 percent rotenone) and 3 pounds of fish-oil soap in 100 gallons of water, 400 gallons to an acre, killed 90 percent of the beetles.

Much of the life-history of this species is not known, but the beetles are found on the bogs from early August to very late October. They may be gathered readily from the cranberry vines by sweeping with an insect net, especially on warm sunny days. They generally crawl, but often fly freely. They feed voraciously, attacking both the upper and the lower surface of the cranberry leaves and fretting their edges. They mate freely.

[1] Mass. Agr. Expt. Sta. Bul. 315, p. 31, 1935.

[2] Mass. Agr. Expt. Sta. Bul. 168, p. 33, 1916.

The females lay their eggs throughout September. They cover each egg with a rough case made up of pellets of their dung deposited on it gradually as it is laid. To do this, they hold the egg and case to the tip of their abdomen and rotate them there slowly with their hind feet, supporting themselves meanwhile with their two other pairs of legs.

Most of the encased eggs are dropped on the sand under the vines but some lodge among the vines and may be swept from them with an insect net. The eggs themselves are oval, smooth, yellowish white, translucent, and about a fortieth of an inch long. The cases are green at first but turn brown as they dry. They are roughly oval and about a twenty-fifth of an inch long.

This insect also attacks cranberry vines in New Jersey sometimes. It has been taken in Framingham and Sherborn, Mass., and it ranges south to Florida where it is abundant. It is found on wax myrtle[1], huckleberry, and especially fetter bush[2].

Cranberry Weevil (*Anthonomus musculus* Say).

As it is considerable trouble to prepare the Bordeaux mixture–calcium arsenate–soap spray advocated as a treatment for this pest[3], attempts were made to find a more satisfactory insecticidal control.

Kerosene applied as a spray at the rate of 100 gallons an acre, on June 11, killed only a small percentage of the beetles. This treatment did very little injury to the vines or crop, though the blossom buds were well developed when it was applied.

A hundred pounds of undiluted very high-grade pyrethrum dust (made from flowers grown in Kenia and with a 1.6 percent pyrethrin content) an acre was tried once and seemed to give a good kill. Fifty pounds of this dust per acre was not effective. Pyrethrum has not controlled this insect heretofore.

A hundred pounds of derris dust (1 percent rotenone) an acre, applied June 5, gave a poor kill.

A spray of 8 pounds of derris powder (4 percent rotenone) and 4 pounds of fish-oil soap in 100 gallons of water, used at the rate of 400 gallons an acre, failed to give a good kill.

Cranberry Flea-beetle (*Systena frontalis* Fab.). The only effective treatment for this insect heretofore known was the Bordeaux mixture–calcium arsenate–soap spray used to control the cranberry weevil (see above). Unfortunately, only the flea-beetle adults can be treated with a spray. As they are active from July till late September, an arsenical spray, to be effective, must be applied at a time when it is likely to leave a residue on the berries. Moreover, the seasonal history of the insect precludes a satisfactory control by flooding. Treatments with other insecticides were therefore tried.

A hundred pounds of undiluted high-grade pyrethrum dust (0.9 percent pyrethrin content) an acre, applied August 13, was very effective in killing the beetles. Fifty pounds of this dust to an acre gave only a fair kill.

A spray of 10 pounds of derris powder (4 percent rotenone) and 1 pound of Areskap in 100 gallons of water, applied at the rate of 400 gallons an acre on August 11, also killed the beetles well.

Cranberry Root Grub (*Amphicoma vulpina*). Many of the male beetles were seen in flight on Beaton's Old Colony bog near South Yarmouth on July 17. Several square rods of the bog showed much injury from the grubs. Grubs were found in this area. The insect has never been found further east on the

---

[1] *Myrica cerifera* L.

[2] *Lyonia nitida* Bartr.

[3] Mass. Agr. Expt. Sta. Bull. 239, p. 62, 1928.

Cape than this or on Marthas Vineyard or Nantucket. It has done marked injury in Wilmington, Mass., and in Rhode Island.

Cranberry Spittle Insect (*Clastoptera*). A spray of 5 pounds of derris powder (4 percent rotenone) and 4 pounds of fish-oil soap in 100 gallons of water, applied at the rate of 400 gallons an acre on June 16, gave a poor kill of the nymphs in their spittle; but 6 pounds of derris powder (4 percent rotenone) and 4 pounds of fish-oil soap in 100 gallons of water, applied at the rate of 400 gallons an acre, gave a fair kill; and 8 pounds of derris powder (4 percent rotenone) and 3 pounds of fish-oil soap in 100 gallons of water, used at the rate of 400 gallons an acre on June 16, killed nearly all the nymphs. This last spray seems to compete on even terms with nicotine sulfate in both cost and effectiveness as a treatment for this pest, and, as the cost of derris is in time likely to fall much more than that of nicotine sulfate, it should perhaps be preferred.

A spray of 200 gallons of water-white kerosene an acre, applied on June 16, did not kill many of the nymphs. This treatment destroyed the crop but injured the vines only moderately.

Gypsy Moth (*Porthetria*). The nearly full-grown caterpillars were treated with derris sprays with results as follows:

1. Four pounds of derris powder (4 percent rotenone) and 4 pounds of fish-oil soap in 100 gallons of water, 400 gallons to an acre, killed only 40 percent.
2. Six pounds of derris powder (4 percent rotenone) and 4 pounds of fish-oil soap in 100 gallons of water, 400 gallons to an acre, killed only 75 percent.

Black-headed Fireworm (*Rhopobota*). A spray of 5 pounds of derris powder (4 percent rotenone) and 4 pounds of fish-oil soap in 100 gallons of water, 400 gallons to an acre, killed 75 percent of the worms; 6 pounds of derris powder (4 percent rotenone) and 4 pounds of fish-oil soap in 100 gallons of water, 400 gallons to an acre, killed 85 percent of the worms; and 8 pounds of derris (4 percent rotenone) and 3 pounds of fish-oil soap in 100 gallons of water, 400 gallons to an acre, killed 98 percent of the worms. While this last spray is very effective, it is too costly at present to compete as a treatment for this pest. However, as the price of derris is likely to decline very materially as time goes on, it has good long-range promise.

Cranberry Fruit Worm (*Mineola vaccinii*). The following special attempts were made to find a more effective insecticidal control for this pest:

1. Undiluted high-grade pyrethrum dust (0.9 percent pyrethrin content) was applied at about sunset at the rate of 100 pounds an acre to the same area of a cranberry bog on each of the following dates, with the vine conditions noted:

June 29 — Vines in full bloom.
July 5 — Vines in bloom.
July 11 — Vines going out of bloom.

The dust did not appear to affect the setting of the fruit. It was estimated that fruit worms took about 35 percent of the berries on the dusted area as compared with 50 to 90 percent on untreated bog nearby.

2. A spray of 10 pounds of derris powder (4 percent rotenone) and 2 pounds of fish-oil soap in 100 gallons of water, applied at the rate of 400 gallons to an acre on July 13, the vines being out of bloom, controlled the insect much better than any insecticide ever tried before, it being estimated that the worms took less than 10 percent of the berries as compared with 35 to 90 percent on surrounding areas. The treatment did not seem to affect the vines or crop.

3. The derris spray just mentioned was also used early in August on plots where fruit worms were abundant. It killed fully a third of the worms in the berries.

Trichogramma minutum. Work with this important parasite of the fruit worm was continued. California Insectaries, Inc., Glendale, California, donated 100,000 of the dark form for this. These parasites had been bred from individuals reared from fruit worm eggs on cranberries collected on bogs in Wareham, Mass., in 1935. They were all put out on a bog near East Wareham that is much infested with fruit worms nearly every year. As continual showery weather greatly interfered with the proper handling of the parasites and with their activity, it is perhaps not surprising that no positive results were obtained with them.

Kerosene and Pyrethrum Extract. A satisfactory machine for applying this mixture as a fog or vapor was built and used rather extensively on experimental plots. The mixture was used in different proportions and amounts up to the limit of any possible economic advantage. It failed to kill cranberry weevil beetles (*Anthonomus*) and black-headed fireworms (*Rhopobota*) to any considerable extent. The best kill of the blunt-nosed leafhopper (*Ophiola*) was 80 percent. There is little reason to expect anything of value from further work along this line, for pyrethrum dust is more easily applied and more effective.

Prevalence of Bog Pests. Notes on the relative general abundance of pests on Cape Cod bogs in 1936 follow:

1. Black-headed fireworm (*Rhopobota*) rather less plentiful than usual, much less than in 1935.
2. Fruit worm (*Mineola*) rather destructive but somewhat less so than in 1935.
3. Weevils (*Anthonomus*) and flea-beetles (*Systena*) more prevalent than usual.
4. Fire beetle (*Cryptocephalus*) — more widely abundant than ever before. (See above).
5. Brown cranberry spanworm (*Ematurgia*) somewhat more plentiful than normal.
6. Gypsy moth more destructive in Plymouth county than for many years.

Cold Storage of Cranberries. (C. I. Gunness, H. J. Franklin, and C. R. Fellers.) A study of home cold storage of cranberries as compared with the storages commonly used has been contemplated a long time. The Department of Agricultural Engineering, the Department of Horticultural Manufactures and the Cranberry Station cooperated during the fall in beginning this neglected investigation. While the work has not gone far enough at the time this is written to call for a detailed report, it may be said that positive results already obtained seem to very amply justify the venture.

Control of Cranberry Bog Weeds. (Wm. H. Sawyer.) Twenty-three different chemicals, alone and in combination, were tested as controls for bog weeds during the season of 1936, 381 plots being treated. Kerosene, sodium arsenate, sodium arsenite, sodium chloride, sodium nitrate, ammonium sulfate, iron sulfate, and calcium chloride were found useful against one kind of weed or another. Of these, kerosene, sodium arsenite, and iron sulfate proved to be the most generally useful. The discovery that kerosene is effective against such difficult weeds as brambles, loosestrife, horsetail, and scouring rush was especially gratifying. The experiments showed that kerosene kills weeds best and harms cranberry vines least when used late in the spring, when the weeds are only partly grown and the vines are still nearly dormant.

With the generous help of the United Cape Cod Cranberry Co., excellent photographs and colored film strips of some 60 species of cranberry bog weeds were made for extension work.

COOPERATIVE CRANBERRY INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station

H. F. Bergman, Senior Pathologist, U.S.D.A., in Charge

Development of Strains of Cranberry Resistant to False Blossom. (H. F. Bergman and W. E. Truran.) Reciprocal crosses have been made between Early Black and each of the four varieties, Centennial, McFarlin, Paradise Meadow, and Shaw's Success; and between Shaw's Success and Centennial, McFarlin, and Paradise Meadow. In addition to these, crosses of McFarlin x Aviator, Paradise Meadow x Aviator, and Shaw's Success x Aviator were made also. From 30 to 60 percent of the flowers pollinated in the various combinations set fruit. Seeds from these crosses will be planted during January and February.

Seedlings from crosses made in 1934 were set out on the bog during the past summer. Although the season was very hot and dry very few of the seedlings were lost.

Investigations on the Effect of Copper on the Growth of Cranberry Vines. (H. F. Bergman and W. E. Truran.) Vines which had been sprayed twice in 1935 with Bordeaux mixture came through the winter flood in much better condition than those not sprayed. Only a small percentage of dead terminal buds and uprights were found on vines that had been sprayed, while on unsprayed vines 30 to 40 percent of the terminal buds and also many entire uprights were dead. The leaves of sprayed vines were much greener than those of unsprayed vines. By measurement of the chlorophyll content it was found at the middle of May, a month or more after the winter flood had been withdrawn, that the leaves of sprayed vines had 20 percent more chlorophyll per unit of leaves than those of unsprayed vines. This difference decreased as the season advanced and by the middle of June was no longer evident.

Three to four weeks after the second application of Bordeaux spray it was observed that the sprayed vines were a more intense green than the unsprayed. Measurements of the chlorophyll content of leaves from a sprayed and an unsprayed plot on the State Bog about the middle of August showed that the sprayed leaves had about 15 percent more chlorophyll per unit weight of leaves than the unsprayed ones. The chlorophyll content of cranberry leaves, under usual bog conditions, begins to decrease early in August. In the leaves from sprayed plots no decrease was evident at the middle of August. The darker green color of leaves of sprayed vines was evident up to the time that the berries were picked early in September.

Spraying and Dusting Experiments. (H. F. Bergman and W. E. Truran.) These experiments included tests of combined fungicide-insecticide mixtures of sulfur spray and of copper oxide dusts. For comparison certain plots of each series were sprayed with either 4-1-50 or 5-2-50 Bordeaux mixture with soap. Two applications only of sprays or dusts were made except on one bog where some plots were sprayed three times. Determinations of the amount of copper in the spray deposit on leaves were made at intervals during the summer, the last about two weeks before the berries were harvested.

Better control of fruit rots was secured with Bordeaux than with the other sprays or dusts. Bordeaux 5-2-50 did not give better control of rots than

Bordeaux 4-1-50 for the same number of applications. In one series in which some plots received three applications of Bordeaux, better control of rots was secured with three applications than with two. Delayed application of the first spray on plots receiving only two applications probably accounts for the difference in control. On this bog better control of rots was secured with two or three applications of Bordeaux on plots which had been sprayed twice with Bordeaux in 1935 than on plots which had not been sprayed in 1935. A similar comparison could not be made on other bogs. A commercial Bordeaux (Oxo Bordeaux) applied as a 4-50 or 5-50 spray at the rate of 250 gallons per acre failed to control rots. The amount of copper in the deposit on leaves during the season up to the time that the berries were picked shows a correlation with the degree of control of fruit rots. Penetrol or Prestol with Bordeaux did not improve the adherence of the spray film nor give a better control of fruit rots than Bordeaux with soap.

Sulfur sprays not only failed to reduce rots but actually caused an increase as compared with adjacent checks. An oil soluble copper resinate (Palustrex) in kerosene 1:4 or 4:10, with one gallon of pyrethrum extract (8 pounds of pyrethrum flowers) added for each ten gallons of spray mixture and applied at the rate of 10 gallons per acre; or one gallon of Palustrex (copper resinate) as an emulsion in 50 or 75 gallons of water, with one quart of pyrethrum extract added for each 50 gallons of diluted spray, and applied at the rate of 175-200 gallons per acre caused severe burning of buds, flowers, and young leaves. When applied as a water emulsion, at either concentration, at the rate of 200-250 gallons per acre before the flower buds began to open, there was no apparent injury. The copper resinate sprays gave no control of fruit rots either when applied in kerosene or as an emulsion in water. On plots on which much burning injury occurred, the amount of rot was greater than on adjacent check plots. Two applications of a dust made up of 3 pounds of red copper oxide, 3 pounds of chemically hydrated lime and 6 pounds of Bentonite, or of a commercial red oxide (A-S) at the rate of 60 pounds per acre reduced very little the amount of rot present when the berries were picked but reduced the amount of rot up to December 1 by 20 to 30 percent.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Some Factors Affecting the Properties of Whipped Cream. (W. S. Mueller, M. J. Mack, and H. G. Lindquist.) Additional factors studied during the past year were the effect of freezing milk prior to separation and the effect of freezing cream on the whipping ability of the cream.

Cream obtained from partly (13 percent solid) frozen milk was whipped with no marked effect on the whipping properties.

Partial freezing of the cream (50 percent solid), either before or after pasteurization, had no significant effect on the whipping qualities of the cream. Total freezing of the cream before pasteurization destroyed the whipping properties of the cream, while total freezing of the cream after pasteurization was only slightly detrimental.

These results have a practical significance because they indicate that if the cream should be totally frozen while in the hands of the producer, most of the whipping properties would be destroyed. If the cream should be frozen after it has been processed, for instance while standing on the customer's doorstep, then the whipping properties would be only slightly damaged.

Studies under this project have been published as Bulletin 335 of the Massachusetts Agricultural Experiment Station.

The Effect of Aging Treatments on the Tyndall Phenomenon of Gelatin-Water Solutions. (W. S. Mueller.) In this study on the effect of temperature treatments on the light-scattering ability of gelatin sols and gels, a need was felt for a tyndallmeter which would be extremely sensitive to changes in light intensity, and would permit control of the temperature of the gelatin while determinations were being made. After considerable preliminary experimental work, a photoelectric tyndallmeter was assembled in the dairy laboratory. This instrument uses as its light-measuring elements two vacuum photo-tubes, one of which measures the light transmitted from the solution under observation while the other measures a fraction of the incident light after passing through two Nicol prisms. The photo-tubes are electrically opposed and the current is balanced by rotating the second Nicol prism. A sensitive galvanometer is used as the indicating instrument. The relative intensity of the Tyndall cone is measured in terms of angular degrees in which the Nicol prism must be rotated in order to balance the photo-tubes. The angular degrees are converted into relative light intensities. With this apparatus it is possible to observe the intensity of the Tyndall cone throughout the aging period without disturbing the gelatin solution cell.

Among the advantages of the tyndallmeter here described are: Control of temperature of the solution under observation; circumvention of moisture condensation on the solution cell when using temperature below that of room temperature; a null measurement, indicated by a sensitive galvanometer; a quickly established equilibrium; a negligible drift; and elimination of the personal error which is encountered when comparing two similar intensities of light with the eye. Furthermore, the instrument can be readily converted into a turbidity meter. The chief disadvantages are that it is neither compact nor portable.

A detailed description of this instrument has been prepared for publication and will be available for distribution in the near future.

Observations with the photoelectric tyndallmeter during the past year confirm a previous report that a high initial (68° F. for 4 hours) aging temperature increases the size or number of gelatin micellae.

Nutritive Value of Chocolate-Flavored Milk. (W. S. Mueller, and W. S. Ritchie, Department of Chemistry.) This study was undertaken with the hope of demonstrating by animal feeding experiments whether the addition of cocoa to milk changes the nutritive value of the milk. Also, it was hoped to secure some data which might aid health officials in setting up standards for chocolate milk.

The effect of the addition of varying percentages of cocoa to mineralized whole milk was studied by means of growth experiments on 72 albino rats. When fluid chocolate milk containing more than one percent of cocoa was fed *ad libitum*, the rate of consumption decreased as the percentage of cocoa increased. When cocoa was added to whole milk powder and fed in controlled amounts, the 1 percent cocoa diet was equal to the whole milk diet; the 2.5 percent cocoa diet gave a questionable retardation rate of growth; and the 4 percent cocoa diet definitely retarded growth. When the rats received the 7 and 10 percent cocoa diets, the feces in the intestinal tract were very hard and there was a greater accumulation of food material in the ceca than was the case in the control group. Studies of intestinal flora showed no distinctive changes for the whole milk, 1 percent, and 4 percent cocoa diets. The addition of 1 percent cocoa to a straight milk diet had no significant effect on the fecal pH.

Since the experiments in this study were conducted with laboratory animals only, no direct application to human nutrition can be made. Assuming, however, that these results may have some application to human nutrition, we may conclude that the cocoa in average commercial chocolate milk, which is a trifle over 1 percent, does no harm nor does it enhance the nutritional value of the milk.

Vitamin C Content of Dairy Orange Beverages. (M. J. Mack, in cooperation with C. R. Fellers, Horticultural Manufactures.) This project has been completed during the past year and the results published in *Food Research*, May-June 1936. The orange-flavored drinks, now being sold by many dairymen, were found to be relatively poor sources of Vitamin C. They contain on the average only about 10 percent as much vitamin C as fresh orange juice, and lose from 15 to 20 percent of their vitamin C during storage for 24 hours at 40° F.

Sodium Alginate as a Stabilizer for Ice Cream. (M. J. Mack.) Since the use of sodium alginate in ice cream is increasing, the product was compared with gelatin, which is still the most widely used stabilizer for ice cream. Sodium alginate, when properly incorporated in the mix, proved to be a satisfactory stabilizer, producing mixes of relatively uniform viscosity which whipped readily to the desired overrun during the freezing process. The finished ice cream was smooth in texture and exhibited desirable melting characteristics.

The use of sodium alginate as a stabilizer in ice cream is described in Contribution 255 of the Massachusetts Agricultural Experiment Station which appeared in the November 1936 issues of the *Ice Cream Trade Journal* and *Ice Cream Review*.

The Effect of Added Iodine on the Properties of Milk. (J. H. Frandsen, W. S. Mueller, and Myer Glickstein.) Much work has been done on mineral deficiencies in the human body, and the study of iodine in its various forms has occupied the time of many investigators. The use of iodized milk is sometimes advocated in cases of iodine deficiency. If milk is to be iodized, it is of course essential that there be no harmful effects on the properties of the milk.

So far as work on the physical and chemical properties of milk has progressed, there is no substantial indication that the heat and alcohol stability of the milk are affected unless abnormally large amounts of tincture of iodine are added. No differences in the creaming ability and viscosity were noted, and the whipping ability of the cream from iodized milk seemed to be improved. Further studies are in progress.

Special attention has also been given to the effect of added iodine on the enzymes in milk. The work is still in progress, and the following results are tentative only. The iodine had a paralyzing effect on the activities of the digestive enzymes, both those added to milk and those normally found in milk. The action of pepsin and trypsin was hindered by iodine up through 48 hours of incubation; but after 72 hours, the paralyzing effect of iodine was not noticed. Iodine retarded the activity of steapsin even after 72 hours of incubation. In toluene-preserved samples, iodine at the rate of 50 p.p.m. had a slight activating power on rennin, but beyond that concentration, iodine was toxic to rennin. In non-preserved samples, there was a decline in the activity of rennin with an increase in iodine concentration. There was a definite decrease in the peroxidase activity of milk with increasing amounts of iodine added. In toluene-preserved samples, the catalase activity of milk increased slightly up to a concentration of 100 p.p.m. of added iodine, but beyond this point catalase activity decreased. In non-preserved samples, there was a definite decrease of catalase activity with an increase in iodine concentration. The amylase activity of milk was inhibited by an increase in iodine concentration. The lipase, protease, and oxidase are present in milk in such minute amounts that it has not been possible to make an accurate study of the effect of added iodine on them.

Iodine Tolerance of Albino Rats. (J. H. Frandsen, W. S. Mueller, and Myer Glickstein.) A preliminary feeding experiment with albino rats is under way, to determine the iodine tolerance of rats when fed varying doses of iodine in milk and in water. The rations were so calculated as to give approximately the same food constituents, except that one group received iodine in milk and the other group received its supply of iodine in water. Only tentative conclusions can be drawn at this time.

The rats receiving iodine in milk averaged slightly more in weight than those receiving it in water. Studies on the possible effect on the reproductive ability of the rats are now in progress.

Pasteurized versus Buddeized Milk. (J. H. Frandsen, W. S. Mueller, and Myer Glickstein.) Buddeized milk is raw milk to which hydrogen peroxide has been added in amounts sufficient to destroy bacteria. In this experiment pasteurized and Buddeized milk were fed to groups of rats. So far there is little indication of difference between results obtained by the two milks. The work will be continued.

A Study of the Efficiency of Water Heaters, Electric Sterilizers, and Electrically Operated Cooling Tanks. (J. H. Frandsen, H. G. Lindquist, and Myer Glickstein.) During the year attention has been given largely to a study of the efficiency and economy of water heaters and electric sterilizers. Preliminary work indicates that electric units for the sterilization of dairy utensils are efficient in reducing bacteria counts, and are economical wherever electricity is available at low cost. Most of these sterilizers are of simple construction and easy to operate. Data are being assembled for publication.

A Study of the Possibilities of Milk, Cream, and Plastic Cream in the Development of New Products such as Combinations with Honey, Fruits, Cheese, and other Flavors of Various Kinds. (J. H. Frandsen and Myer Glickstein.) New products such as combinations with certain fruits, nuts, and some of the well-known hard and semi-hard cheeses are being made and studied.

A Study of the Changes that Occur in the Storage of Frozen Sweet Cream. (H. G. Lindquist.) This project is being continued, using such materials as sodium caseinate and Dariloid to prevent frozen stored cream from oiling off when thawed.

DEPARTMENT OF ECONOMICS

Alexander E. Cance in Charge

Decentralization of Industry and Part-Time Farming in Massachusetts. (David Rozman.) One of the main factors determining the extent to which the development of part-time farming will progress in various sections of the Commonwealth is associated with the trend in location of industrial plants in smaller communities as against larger populated centers. To obtain a picture of this trend as it has developed in the past a study was made of over 200 cities and towns in Massachusetts for which figures were available. The results are presented in graphic form, indicating for each town or city the historical trend since 1837 of the number of employees, population, and the number of industrial plants. Likewise statistics for the last 20 years were compiled, indicating the trends for 24 major Massachusetts industries in number of establishments, wages, wage-earners, and value of products. The results of this study are being published in the form of a Station bulletin.

Recent Changes in Consumer Demand for Milk and Some Factors Affecting It. (David Rozman.) This project has been initiated recently and the work is just beginning. Within recent years there have been considerable changes in consumer demand for milk in various markets of the State. Some of these changes have been due to the general trend in consumption of milk and dairy products in connection with changing consumption habits. Other important changes have occurred in connection with business fluctuations, unemployment, and reduced purchasing power of the population in various communities. In addition, there has been a considerable increase in the extent of milk regulation. It is the objective of this project to ascertain as far as possible how each of these new developments has affected the consumption and demand for milk.

In attempting to collect the essential information for the project several methods of procedure will be followed. In a few individual markets it is proposed to make a survey of milk consumption among a group of individual families. The State Milk Control Board will yield considerable information which will be analyzed in the light of the present study. Likewise supplementary information will be obtained from the examination and study of data available in the offices of local milk inspectors and in the record books of milk dealers.

A Study of Farm Organization and Soil Management Practices in Massachusetts in Relation to Agricultural Conservation and Adjustment, with Special Reference to the Formulation of a Program under the Soil Conservation and Domestic Allotment Act. (David Rozman in cooperation with the Departments of Agricultural Economics and Farm Management and Agronomy.) This project was undertaken last summer at the request of the Bureau of Agricultural Economics and the Agricultural Adjustment Administration of the United States Department of Agriculture and was in some respects a continuation of the cooperative Agricultural Adjustment project carried on under similar arrangements a year ago. The particular problem this summer was to study hay and pasture improvement practices, to provide a better factual basis for determining desirable adjustments in the agriculture of individual farming areas and for the administration and operation of the 1937 land conservation program.

The investigational work of the project was carried on under two divisions:

1. Investigation of individual farm experiences in pasture improvement by types of pastures under different conditions. To obtain information for this section a field survey was carried on last summer with the result of obtaining very detailed information on pasture and hay practices by individual plots on 113 farms located in different sections of the State. In addition, it was possible, with the assistance of a specialist from the United States Soil Conservation Service, to map out 50 farms showing in detail for each field the type of soil and cover and the degree of erosion and slope.

The survey showed that moderate sheet erosion and occasional gullies occur on cultivated land in western Massachusetts and that wind erosion is a serious factor in the Connecticut Valley. Generally speaking, however, soil erosion was not found to be a serious problem in Massachusetts. Of the land area surveyed, an average of 12 percent was in cultivated crops, 36 percent in pasture, 25 percent in hayland, 25 percent in forest, and 2 percent was idle.

2. A summary of available technical research material on hay and pasture improvement. Under this section material was collected by Dr. Colby of the Agronomy Department on experimental data from the college plots and data from the extension demonstration projects on individual farms by extension agronomists. The field data have been tabulated and analyzed to show the results of pasture and hay improvement practices under varying conditions, indicating the costs involved, the changes in farm management practices, and the effect on soil conservation and farm economy.

To show the results of various pasture improvement practices in a more definite and detailed way, 13 farms were selected for an intensive budget analysis and changes in farming operations.

As a result of this study recommendations are being sent to Washington as a factual basis for the administration of the Soil Conservation Act in this State.

DEPARTMENT OF ENTOMOLOGY

A. I. Bourne in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne, and W. D. Whitcomb, Waltham.)

Oil Sprays for Dormant Applications. From the standpoint of the orchardist, the winter of 1935–36 was not featured by unusual conditions. Although steady cold weather prevailed during late January and most of February, there was practically no injury to apples and but little more than the normal winter-killing of peach buds.

The unseasonably high temperature of late March, following the rapid disappearance of the snow during the period of the flood, advanced the seasonal development of nearly all types of fruit so that by the end of the month trees were three to four weeks ahead of normal. This stimulation was also reflected in the early appearance and rapid development of many insect pests. April, however, was colder than usual so that this rapid development was retarded, and throughout most of the State the delayed dormant sprays were applied at the usual time.

The practice of using oil sprays, discontinued by many growers in 1934 and 1935 because of injury to their trees the previous winters, again became general and no reports of injury were received. There was a slight increase in the use of tar distillate oil sprays, particularly in orchards where bud moth or rosy aphid was a problem, and satisfactory results were reported. For the most part, however, growers continued to apply the conventional types of oil sprays and confined themselves to old and well-established brands.

Outstanding among the new types was Ready Mix Kleenup manufactured by the California Spray Chemical Company, a light-bodied product of the miscible type, very stable, with a high percentage of active oil. It consisted of 95 percent petroleum oil, 4 percent cresol compounds and but 1 percent inert ingredients (chiefly water). This product required a special method of preparation for spraying and more time for final dilution than does the usual type of oil sprays. In the course of mixing, whether the material was simply run through the pump or whether the spray nozzles were opened and turned back into the tank, considerable froth was developed. This was believed to be due to hard or chlorinated water. (The manufacturer furnishes a "conditioner" to remedy this.) It was noted that when this froth was allowed to stand, a considerable amount of free oil quickly separated out. This separation would make it difficult to determine the strength of the oil in the spray applied and might also be a source of danger to the trees. The material, however, proved very effective against overwintering eggs of the European red mite and compared very favorably with the standard type of Kleenup, as shown in the following table.

Treatment	Dosage per 100 gals.	Number of mites per 100 leaf clusters	Percentage of clusters free from mites	Average number of mites per leaf	Percentage of control
Ready Mix Kleenup	3½ gals.	76	85	0.13	98
Flowable Kleenup	4 gals.	189	83	0.3	95
Check	—	3,786	6	6.3	—

Spray Materials for the Control of Gladiolus Thrips. The experiments conducted in 1936 were of two types.

1. Comparison of effectiveness of derris and a thiocyanate in control of the gladiolus thrips. In these experiments Derrisol, Ku-ba-tox and Lethane 420 were used as spray materials at dilutions of 1-600. Four applications were made at weekly intervals when the infestation began to develop, and the comparative effectiveness was determined by the amount of injury to the plants and blossoms. The derris sprays were superior to the thiocyanate compound. These tests again demonstrated that if spraying is delayed until a heavy infestation has developed, and particularly after the flower spikes have appeared, no spray can be depended upon to give satisfactory control.

2. Comparison of the effect of certain contact sprays and stomach poisons upon corm production. In 1935 observations on corms of mixed varieties indicated that in the absence of a heavy thrips infestation certain stomach poisons reduced the average weight per corm of the corms produced. In 1936 experiments in which various insecticides were applied to plots of the same variety substantiated this belief. All stomach poisons reduced the average weight per corm below that of the unsprayed checks.

Substitutes for Lime-Sulfur in Summer Sprays for Orchards. Tests of these materials were continued in cooperation with the Department of Pomology. A period of unseasonably high temperature in late March which caused fruit buds to unfold much earlier than usual was followed by cold weather and frequent rains during April that slowed down further development. As a result, new growth was exposed to scab infection for a long period. The test blocks in the college orchard were given an emergency pre-pre-pink application of lime-sulfur 2-100, to give protection up to the time of the first spray of the regular schedule.

Two new types of colloidal sulfur (paste form) which had shown great promise in preliminary trials the previous year were studied under orchard conditions. A comparison was made of dry lime-sulfur used at standard strength and at a somewhat reduced dosage recommended by the manufacturer in the hope of avoiding foliage injury.

In all of the above tests liquid lime-sulfur 2-100 was applied in the pre-blossom and calyx sprays and the new materials in the four subsequent applications. Liquid lime-sulfur was applied in one section at 1-50 strength in the pre-pink, 1-75 in the pink, and 1-100 in the calyx applications, in an attempt to secure maximum scab control at the most critical period and at the same time lessen the danger of foliage injury. A wettable sulfur was used in the summer sprays in this section. All of the tests were compared with the standard sprays recommended for the State: lime-sulfur 1-50 in pre-blossom and calyx applications and a wettable sulfur in the four cover sprays. Lead arsenate was used in all the tests: 3 lbs. per 100 gals. in pre-blossom and 3d cover sprays; 4 lbs. per 100 gals. in calyx, 1st and 2d cover sprays; and 2 lbs. per 100 gals. in the 4th cover spray.

On the whole the season was not of a type to induce severe spray burn, and no serious injury was noted in any of the test blocks. A slight amount of marginal burn was noted, however, following the early sprays with lime-sulfur. No burn was observed from summer applications of wettable sulfur. It was hoped that a reduced dosage of liquid lime-sulfur in the pink and calyx applications would prevent spray burn, but this did not prove to be the case, and in the section sprayed with half strength lime-sulfur and wettable sulfur, spray injury was as conspicuous as where lime-sulfur at standard strength was used alone. Reducing the dosage of dry lime-sulfur did not materially lessen the amount of foliage injury but gave satisfactory control of scab. Some russeting of McIntosh fruit was noted in the sections which received the colloidal sulfurs in summer applications. The relative effectiveness of these sprays in control of scab and insect pests was measured on McIntosh. The results are as follows:

Material Tested	Percentage of Clean Fruit	Percentage of Fruit Showing Injury from —		
		Scab	Curculio	Codling Moth
King	59.9	5.1	4.9	16.9
Linco	81.6	2.1	1.3	6.2
Lime sulfur (modified)	90.5	0.6	1.2	5.5
Lime sulfur-post calyx wettable sulfur	92.2	1.1	0.9	2.8
Lime sulfur-magnetic sulfur, half strength	93.3	1.1	0.4	1.6
Dry lime sulfur (6¼ lbs.)	90.5	1.4	0.7	5.5
Dry lime sulfur (8 lbs.)	73.6	0.3	10.6	9.9
Check	3.4	86.1	15.6	14.5

Derris and Pyrethrum for the Control of Greenhouse Leaf Tier on Snapdragons. In two separate experiments on snapdragons grown in the greenhouse from January to May, commercial pyrethrum sprays diluted 1-200 and 1-400 and applied at approximately 10-day intervals have given good control of the greenhouse leaf tier. A derris extract containing 1½ percent rotenone was also satisfactory. When the pyrethrum spray was diluted 1-800 the control was poor, evidently due to the low concentration of the insecticide.

Washes of derris powder used at the rate of 2 pounds and 3 pounds in 50 gallons permitted 66 percent moderate or severe injury and were surprisingly unsatisfactory.

Derris and pyrethrum clay dusts diluted with inert clay were less effective than the liquid sprays and left a very objectionable residue on the plants which generally eliminates them from commercial use on snapdragons.

Control of Cabbage Maggot with Mercury Compounds. The natural field infestation of the cabbage maggot at Waltham was again very high and 82 to 94 percent of the untreated plants were killed or severely injured. Corrosive sublimate, 1 ounce in 10 gallons of water, continued to give excellent protection. One application when the eggs were first found (May 6) gave practical protection to 94 percent of the plants with a minimum of small or otherwise unsalable heads. Later applications were not satisfactory, however, and emphasized the importance of early treatment.

Experimental treatments with calomel (mercurous chloride) both as a dust and as a paste applied to the roots and stem of the seedlings when they were transplanted gave promising results and reduced the labor of application. As a dust, pure calomel shaken on the roots protected 88 percent of the plants from moderate or severe injury and produced the most salable heads of the experiment. When the powdered calomel was mixed in the proportion of 1:1 and 1:3 with inert clay the protection was reduced to 60 and 42 percent respectively.

As a wet treatment, calomel was mixed with various adhesive materials in the proportions of 1:1, 1:3, and 1:9 and wet with sufficient water to make a thick paste which covered the roots and lower stem with a thick coating. Mixtures with laundry starch, clay, and clay plus fish oil, gave 76 to 96 percent protection and were the most satisfactory. The addition of fish oil did not increase the effectiveness of the clay mixture. There was no significant difference between the 1:1 ratio and the 1:3 ratio, but the 1:9 ratio was generally less effective in all of the mixtures.

Mixtures of calomel and calcium caseinate, lead arsenate and sulfur (15–85), and lead arsenate and lime (20–80) in paste form caused serious injury to the cabbage seedlings and killed many of them.

All of the paste mixtures slightly checked the growth of the seedlings by sticking and matting the roots together. The plants dipped in the clay and starch mixtures recovered quickly and formed new roots so that there was little decrease in the size or earliness of head, but the mixture must be improved to prevent this condition before the treatment can be considered practical.

Control of the Squash Vine Borer. In 1936 the field infestation of the squash vine borer was much less than in previous years, and at Waltham the average infestation in untreated Hubbard squash vines was 1.13 borers per vine.

The most effective insecticidal treatment was a spray prepared from cube powder at the rate of 5 pounds in 100 gallons of water, which was made wettable with fish-oil soap at the rate of 1 quart in 100 gallons of spray. This reduced the injury 74 percent. Spraying with nicotine sulfate 1-500 plus 1 percent of summer oil was again more effective than nicotine sulfate 1-250. Dusts were not so effective as in 1935 although they protected the vines from serious injury and were applied much more quickly and easily than the sprays. Pyrethrum-clay dust 30-70 gave slightly better control than derris or cube dusts.

The records in these studies are obtained by pulling up the roots and cutting off and splitting approximately four feet of the vine stem. This is usually done about August 20, and for the second year an excellent crop of squash has matured on the vines which live from the nodular or secondary roots after the records are taken.

Control of Onion Thrips. (A. I. Bourne.) Although weather conditions during the late spring and early summer were favorable for thrips development, the insects were late in appearing and attained only moderate numbers during the season. Many fields throughout the Connecticut Valley were comparatively free from thrips and no instances of severe injury were noted. The submergence of much of the onion-growing area under several feet of water and the erosion caused by the flood in March apparently had little effect upon the hibernating thrips. The insects appeared at approximately the same time and in the same abundance in such areas as in fields above the flood level.

In the experimental plots the infestation averaged only 4 thrips per plant on July 7 and had increased to only 14 per plant by July 20. The peak of abundance occurred from July 27 to August 1 with an average of 40 thrips per plant, or less than 2 thrips per linear inch of plant growth. The numbers dropped rapidly from that date until August 18 when there was a slight increase due to the fact that most of the fields had been killed by blast by mid-August and thrips had necessarily migrated to the comparatively few plants remaining alive.

The materials tested did not show to best advantage because the infestation in the experimental plots was so light, and none of them proved equal to the nicotine–soap combination in their immediate effects. The rotenone compounds however, showed a very pronounced residual effect over a 7-day interval, as shown in the following table.

Treatment	Average number of thrips per plant 1 day after application	Average increase in number of thrips during 7- day interval.
Derris (rotenone)	12.2	8
Niagron (rotenone)	17.9	7.7
Nicotine tannate	12.8	25.8
Oil–Nicotine	17.1	2.9
Nicotine sulfate–Soap	3.9	17.4
Unsprayed	22.8	18.4

The oil–nicotine combination was somewhat slow in becoming effective. It apparently left on the plants a residue that was toxic to thrips and gave greater protection against reinfestation than any material that has yet been tested.

The thrips–resistant varieties selected for study the past season were grown from seed secured through local distributors and are therefore readily available at the present time. Of the six varieties studied, four proved to be as readily attacked by thrips as did Danvers Yellow Globe, the standard variety. Two varieties of Sweet Spanish onions, however, showed a consistently lighter infestation throughout the season, as shown in the following table.

Date	Average number of thrips per plant		
	Danvers Yellow Globe	Sweet Spanish Valencia	Sweet Spanish Riverside
July 14	10.4	8.5	6.4
July 21	14.6	4.7	4.2
July 27	43.4	4.	3.5
Aug. 4	14.1	6.8	4.6
Aug. 11	13.1	14.4	2.1

The appearance of blast terminated the studies in early August. The Sweet Spanish types eventually succumbed although persisting later than Danvers. The increased infestation of the Valencia Sweet Spanish was undoubtedly due to migration from blasted plants of adjoining varieties.

There was very little evidence of the fungous disease of thrips. The prevalence of blast throughout the Connecticut Valley during the last two seasons, which killed the plants before the normal time of appearance of the disease, has apparently reduced this to a position of little importance.

The Spray Residue Problem. (A. I. Bourne.) No further reduction in limits of tolerance on lead residue was made, so that for the shipping season of 1936 the figure remained at .018 grains per pound of fruit for lead and .01 grains per pound for arsenic. This action was to a great extent in recognition of the exceeding persistence of lead deposits on fruit and the difficulty of removal, as well as the complication of the problem presented by the unusually dry weather conditions prevailing between the spraying season and harvest. Analysis of McIntosh fruit which had received the regular sprays up to and including the 3d cover on July 13 showed .019 grains of lead and .012 grains of arsenic per pound of fruit. Such a residue exceeds the present established limits of tolerance for both materials. Fruit receiving the complete schedule of four cover sprays showed .026 grains of lead and .013 grains of arsenic per pound, indicating that even with the dosage of lead arsenate reduced from 3 pounds to 2 pounds per 100 gallons in the late July spray, the amount of residue built up rapidly. Since the 3d and 4th cover sprays are designed primarily for control of apple maggot, the above figures strengthen the recommendation for the use of dusts for those applications, since dusts have proved effective against apple maggot, and analyses have shown no objectionable residue on fruit dusted as late as three weeks before harvest.

In studies of possible substitutes for lead arsenate, Calrite, a product of the Niagara Sprayer and Chemical Company, for the third successive season caused no trace of foliage injury or russeting of fruit on either McIntosh or Baldwin. When supported by the colloidal spreader Fluxit, Calrite also proved substantially equal to lead arsenate in control of plum curculio and codling moth, as shown in the following table.

Material	Percentage of clean fruit		Percentage of fruit showing injury from —					
			Curculio		Codling Moth		Scab	
	McIntosh	Baldwin	McIntosh	Baldwin	McIntosh	Baldwin	McIntosh	Baldwin
Calrite and Fluxit	94.9	85.3	0.2	0.0	0.9	3.2	1.7	1.2
Lead arsenate	92.5	92.9	0.0	0.2	0.4	2.6	6.1	0.2

Both materials were used with the same fungicides: lime-sulfur in preblossom applications, and wettable sulfur in the calyx and four cover sprays. It will be noted that in such a program the calcium arsenate also compared very favorably with lead arsenate in control of scab. Two experimental samples of calcium arsenate, furnished by the Crop Protection Institute and applied in late cover sprays on a block of young non-bearing trees, gave no trace of foliage injury or premature drop of leaves, and both products appeared to be worthy of further tests on a commercial scale.

In a cooperative experiment with the Crop Protection Institute one block of the orchard was devoted to a comparison of an experimentally prepared basic zinc arsenate with standard lead arsenate. One section of the orchard received lead arsenate throughout the season; a section received lead arsenate through the 1st cover spray and basic zinc arsenate thereafter, and in the third section basic zinc arsenate was used throughout the season. Both arsenicals were used at the same dosage and with the same fungicides. The relative effectiveness of these materials on McIntosh was as follows:

Material	Percentage of clean fruit	Percentage of fruit showing injury from — Curculio	Codling Moth	Scab
Basic zinc arsenate	70.8	0.6	3.1	20.2
Lead arsenate and basic zinc arsenate	84.2	0.8	2.5	10.8
Lead arsenate	84	1.2	0.9	13

On the basis of one season's tests the results secured in insect control from basic zinc arsenate were very promising, especially when that material was used in the late summer sprays following lead arsenate in earlier applications. Since these are the critical sprays from the spray residue standpoint, the efficiency of zinc arsenate is significant. No injury to fruit or foliage was noted following the application of either material.

Apple Maggot Control. (A. I. Bourne and W. D. Whitcomb.) The appearance and relative abundance of the adult flies were approximately normal. Observations throughout the State indicated that in well-sprayed orchards and with accurate timing of sprays the insect caused little damage. The abnormal conditions, consequent upon severe winter injury and wholesale removal of border orchards, were much less apparent in 1936 than during the two previous seasons. The problem offered by neglected trees adjoining well-cared-for orchards confronted many growers and appears to be the chief limiting factor in the control of this pest in commercial orchards.

The record of emergence of apple maggot flies under different conditions of soil and exposure, made by Professor Whitcomb at Waltham, is as follows:

Date of Emergence of Apple Maggot Flies, Waltham

	In Sun		In Shade	
	Cultivated	Sod	Cultivated	Sod
Light Soil				
1st fly	June 30	June 23	July 2	July 6
25% flies	July 12	July 11	July 14	July 14
50% flies	July 14	July 16	July 16	July 19
75% flies	July 25	July 24	July 24	July 23
Heavy Soil				
1st fly	——	——	July 7	July 6
25% flies	——	——	July 15	July 17
50% flies	——	——	July 22	July 22
75% flies	——	——	July 26	July 25

The number of flies emerging equalled 30.76 percent of the total and was the smallest since the experiment was started. Dry soil in May and July and a generally low vitality of the maggots developing in the fall of 1935 contributed to the low emergence record. In spite of the small number of flies, a greater emergence in the sun, cultivated, and light-soil cages was consistent with previous records.

Introduction of Parasites of Oriental Fruit Moth in Peach Orchards. (A. I. Bourne.) No new introductions of *Macrocentrus* parasites were made during 1936. Curtailment of funds and personnel at the Federal Laboratory prevented the cooperative arrangement by which such material was secured. Many of the growers, however, purchased and released colonies of the egg parasite, *Trichogramma.*

The early twig infestation of the Oriental fruit moth was very light throughout the State; and apparently the pest had not fully recovered from the heavy mortality caused by the severe winters since 1933, for no serious damage to the crop was reported although the late twig infestation gave promise of a rapid recovery of the insect.

Potato Spraying Experiments. (A. I. Bourne.) Flea beetles were present in about normal abundance and were again the most serious single pest of potatoes throughout the State, although held in check quite satisfactorily in the well-sprayed fields. Leafhoppers, usually very generally abundant in late summer, were later than usual in appearing and the infestation was lighter. Very few fields suffered appreciably from their attack. Potato aphids were more abundant than usual although the infestation was uneven. Many fields of Irish Cobblers suffered severely in late July, and the hot, dry weather of early August favored a rapid development of lice which seriously threatened many fields of Green Mountain. The high temperature, however, favored a rapid action of nicotine sprays or dusts and well-timed applications were very effective.

In the plots devoted to field tests of different insecticides on the standard variety Green Mountain, eleven applications of Bordeaux mixture were made from June 10 to August 24. Insecticides were added to 5-5-50 Bordeaux in five applications from July 15 to August 14. The treatments were duplicated on 1/100 acre plots. Bordeaux mixture itself is an effective repellent for flea beetles, yet each additional material produced increased control. The ranking of the spray mixtures in this respect, measured by successive counts of leaf punctures, was as follows:

(1) Bordeaux plus Calrite (a brand of calcium arsenate).
(2) Bordeaux plus Cubor (rotenone).
(3) Bordeaux plus Niagron (rotenone).
(4) Bordeaux plus Ku-ba-tox (rotenone and pyrethrum).
(5) Bordeaux plus Nicotine Tannate.
(6) Bordeaux alone.

In other words, although good control of flea beetle was obtained in all plots, the best results were secured from calcium arsenate, due to its cumulative effects and greater lasting properties. The rotenone and pyrethrum sprays, while functioning as both contact and stomach poisons, are more temporary, the effective ingredients lasting only a few days before deteriorating, so that no protection is furnished against reinfestation by beetles migrating into the fields.

From the standpoint of aphid control the contact poisons proved very effective in preventing the building up of a serious attack. The nicotine-tannate plots were outstanding in this respect, having an appreciably lighter attack than the others. A serious attack which developed in the Bordeaux and Variety plots was satisfactorily checked by an application of nicotine sulfate on August

14. The spray was applied at a temperature of 85°—87° F. Within three hours after the plots were sprayed the vines were comparatively clear and the ground beneath green with aphids. No further contact sprays were necessary throughout the remainder of the season.

The protracted drought during July and early August was not favorable for high yields, a duplication of the conditions which prevailed in 1935 with similar results. The yield in the experimental plots was as follows:

Material	Yield Bushels per acre
Bordeaux mixture 5-5-50	439.1
*Nicotine tannate	464.4
*Derris (rotenone)	463.7
*Cubor (rotenone)	457.3
*Niagron (rotenone)	456.8
*Ku-ba-tox (rotenone-pyrethrum)	422.7
*Calcium arsenate	420.8

*Combined with Bordeaux Mixture 5-5-50

With flea beetles the outstanding insect pest and in the absence of potato diseases, the higher yield in the nicotine-tannate and rotenone plots is believed to be due largely to the protection furnished against incipient attacks of leafhoppers and potato aphids and reflected the superior appearance of the plants in those plots throughout the growing season.

Three different commercial brands of copper sprays designed for use on potato were compared with 5-5-50 Bordeaux mixture. Eleven applications of each were made. The yield and relative position of each are represented as follows:

Material	Yield (Bushels per acre)
Bordeaux mixture (5-5-50)	469.3
Basic copper sulfate (Sherwin-Williams) + lime	448.4
Potato spray (General Chemical Company)	432.1
Oxo-Bordeaux (Ansbacher-Siegle Corp.)	416.8

Plants in the plots sprayed with the last two materials showed a considerable amount of leaf burn which shortened their growing period. Whether the prolonged growth in the Bordeaux and basic copper plots was due to the protection afforded by excess lime is not known. In view of the comparatively poor showing of basic copper sulfate in 1935, it would appear that the lime present was an important factor contributing to this improvement.

Insecticides for the Control of European Corn Borer. (A. I. Bourne.) Life history studies have shown that young, newly hatched corn borer larvae feed for a short period directly on the leaves of their host plant. On corn the young larvae migrate to the narrow spaces between the unfolding leaves in the central whorls of the main stalk and tillers. After the second or third instars the caterpillars become borers and enter the stalks or the young developing ears. The use of insecticides against this insect is based on the habit of the young larvae of feeding externally during the early period of their growth.

In cooperation with the Federal European Corn Borer Laboratory in New Haven, Conn., the department ran field tests with three contact sprays in half-acre plots of sweet corn on two farms in Hampden County. Each material was run in quadruplicate with a corresponding number of unsprayed areas.

The sprays were applied at 5-day intervals beginning with the first appearance of larvae in each field. Four applications were made between June 19 and July 3 on each farm. A fifth application was made on July 8 on one farm because the corn there had developed more slowly than in the other field although the insect first appeared on approximately the same date in both cases. The materials tested were ground derris (4 percent rotenone), phenothiazine (thiodiphenyl-amine) and tank-mix nicotine tannate. Each material was used at the rate of 12.5 gallons for the first application, 15 gallons for the second and third, and 25 gallons for the fourth and fifth sprays.

The results were based on the total yield from both fields, approximately 20,000 ears being examined. Nicotine tannate and derris were very effective in reducing corn borer damage. Phenothiazine gave fair control. Its failure to measure up to the other materials is believed to be due to its poor suspension qualities which prevented uniform coverage and protection. None of the materials caused any injury to the corn nor did they render it unsafe as fodder. The yield record from one of the farms is as follows:

Treatment*	Total Number of ears	Percentage of Ears			Percentage of Ears Infested but Salable
		Clean	Grade 1 and 2	Infested	
Derris	2,124	95.1	90.0	4.9	57.2
Nicotine tannate	2,447	92.1	88.4	7.9	53
Phenothiazine	2,232	89.9	78.8	10.1	48.4
Check	1,993	77.7	70.4	22.3	45.7

*Four plots totaling one-eighth acre for each treatment.

On each farm the variety tested was Span Cross 2, the earliest variety of yellow sweet corn to mature. Both growers were anxious to secure the full benefit of an early market so that the crop was harvested as rapidly as possible. This allowed a comparatively short time for the infestation of the ears and enabled the check plots to show a much better record than the relative infestation warranted. Practically every stalk in the check plots was infested and many contained 6 to 8 borers and were seriously weakened, while comparatively few stalks in the sprayed plots showed the presence of borers. This is indicated in the smaller yield in the check plots, a difference ranging from 1,048 to 3,632 ears per acre from the yield in the sprayed plots. It is further supported by the relative percentage of salable infested ears. In the derris and nicotine–tannate plots practically all of the borers found were very small larvae; in many cases they had penetrated only a few of the husks or but a short distance into the base of the ear. In such cases the corn itself was not damaged and much of this type went into the market as Grade 1 or 2. Infested corn from the check plots, however, often contained full-grown larvae, and in a majority of cases the ears were worthless. Both growers were able to command the highest market prices because of their ability to guarantee borer-free corn. On the basis of the price scale prevailing at each picking the sales record for the farm mentioned above was as follows:

Treatment	Total sales*	Loss due to borers
Derris	$37.04	$2.22
Nicotine tannate	41.53	4.78
Phenothiazine	36.70	4.90
Check	28.56	8.80

*Sales were from an area of one-eighth acre of each treatment.

The losses could be somewhat reduced in the cases of derris and nicotine tannate because many of the infested ears were marketed. The disposition of such material was, however, not accurately recorded by the growers.

The cost of materials for the season's program on both farms is shown in the following table:

	Number of Applications	Amount of each material	Cost of Materials	
			Derris	Nicotine Tannate
Farm A	4	67½ gals.	$1.40	$1.24
Farm B	5	92½ gals.	1.92	1.69

No figures were available for phenothiazine because the material is still in the experimental stage and no market price was quoted.

The prices of labor on the two farms varied greatly. The labor charges can however, be determined for any individual locality from the estimates of the Federal Entomologists in the Corn Borer Investigation. On the basis of these estimates and our experience in one season, the time required per acre for the first two sprays would average one-half day for one man, and due to the rapid growth of the plants would average a full man-day per acre for subsequent applications.

Insects Concerned in the Dispersal of Dutch Elm Disease. (W. B. Becker.) Further research on the biology of the native elm bark beetle. *Hylurgopinus rufipes*, is in progress. Life history studies indicate that there is one complete generation a year and a partial second. Under some conditions, larvae of the first generation will overwinter and transform to adults the following spring. Due to differences in the rates of development, there is an overlapping of generations. Both adults and larvae have been found overwintering in Amherst. Partially completed work on the development of the immature stages within the bark points to a variation in the number of instars. Soon after the adults emerged from trap logs in August many were seen digging tunnels into the bark of near-by thrifty-appearing elms. These tunnels are of the same type as those dug in the fall, in which to spend the winter, and are similar to the feeding tunnels of *Scolytus multistriatus*, except that *H. rufipes* tunnels have only been found in the bark on the trunks and larger limbs of elms in the field whereas *S. multistriatus* prefer the smaller twigs and buds for feeding tunnels and wounds, according to literature and observations by the author.

Spathius canadensis, a Braconid, was found to parasitize a small percentage of the *H. rufipes* larvae. Numerous mites and several species of insects, of which Collembola were the most abundant, were also found in the brood galleries of *H. rufipes*.

Because *H. rufipes* has been reported taken from several species of trees, freshly cut logs of six species were used in the field and in individual cages as traps for the adults of the first generation which emerged from American elms in August. American elm, slippery elm, red maple, basswood, ash, and red cedar were used. Egg galleries were constructed only in American elm. Numerous holes were dug into the bark of slippery elm, and in some of these there was a live adult. However no egg galleries were constructed. The red cedar and red maple were untouched. Feeding on the basswood was negligible, while the attack of a regular ash bark beetle spoiled the ash log experiment.

Some preliminary experiments were being carried on with subcortical elm bark temperature. The subcortical temperature of elm logs in the sun rose to 122° F. in the experiments recorded.

Studies of Scolytus multistriatus. Preliminary studies on the life history in Massachusetts of the smaller European elm bark beetle, *Scolytus multistriatus*, are being made. This is the beetle which today is considered to be the principal vector of the Dutch elm disease organism. Studies indicate that there may be only one generation a year in this region. Some scouting was done in Western Massachusetts for additional records of the presence of this beetle, near the localities where the insect was found last year. To date no additional outbreaks have been found. However, *H. rufipes* has been present wherever scouting was done.

Other Elm-Boring Insects. Experimental work was also conducted on the habits of two other elm-boring insects, *Saperda tridentata and Magdalis* sp.

Campus Insect Pest Survey. A survey of insect pests present on the shade and ornamental trees (elms, particularly) on the Massachusetts State College campus was made for the purpose of assembling information for a spray program.

Apple Leaf-Curling Midge. (W. D. Whitcomb, Waltham.) The apple leaf-curling midge (*Dasyneura mali* Kieffer) was as abundant in the infested area in 1936 as at any time since it was discovered. In parts of some orchards all new shoots and watersprouts which were susceptible during the oviposition periods of the midge flies were attacked. In Westford a distinct and abundant third generation developed on young trees from eggs laid August 20 to September 1, but in the same orchard on older bearing trees having a good crop of fruit and little or no new growth in August, the number of third generation midges was insignificant or none could be found.

A new infestation of this midge was found at Groton, Massachusetts, which extends the infested area nearer to the large apple growing section of the east-central part of the State. This new infestation apparently was caused by wind-blown midge flies during the spring emergence period, and indicates that further spread of this pest by natural agencies may be expected. Other new infestations were reported and verified at Sanford and Alfred, Maine, and near Rochester, N. Y. The Maine infestation also appears to be the result of spread by wind from a previous known infestation in southeastern New Hampshire.

Collections of mature maggots on cloth-covered frames under specimen trees were concentrated in three periods coinciding with the generations. Maximum collections were made on June 12, August 7, and September 1. Rainfall which softened the rolled leaves influenced the exact time of emergence. Rain fell at approximately the time when the maggots of the first and third generations reached maturity and emergence was normal for the development, but the records indicate that the absence of rain between July 24 and August 7 delayed the maximum emergence of the second generation maggots about 10 days.

By placing bands and tanglefoot on the trunk of the trees under which the cloth-covered frames were erected, it was determined that approximately 10 percent of the mature maggots crawl down the tree and 90 percent of them fall from the leaves and branches.

Corrugated paper bands treated with Beta-Naphthol captured as many maggots on the trunks and branches as did bands of leather, felt, or canvas, indicating that the chemical is not repellent. In the chemically treated bands 34 percent of the maggots were on the band, 28 percent in the corrugations, and 38 percent on the bark under the band. All maggots in or beneath the treated bands were dead except a few which spun cocoons in crevices in the bark under the band but not in contact with the chemical.

Sprays were applied to a block of young Starking trees in an infested orchard. Four applications were made at the height of the oviposition period of the first generation, May 20, 22, 25, and 29; and these were repeated at the corresponding period of development for the second generation, July 7, 10, 14, and 17. By omitting the spray on certain trees at each application, records were secured on the value of 1, 2, 3, and 4 treatments.

On the unsprayed trees the average infestation by the first generation was 42.28 percent infested tips, varying on individual trees from 83 to 3 percent. This variable infestation made conclusive deductions from the results of spray treatments difficult. Average infestations in the sprayed blocks varied from 19.08 to 6.3 percent infested tips, and represented a reduction of 55 to 85 percent. Derris extract, summer oil emulsion, and lime-sulfur were about equally efficient in reducing the number of curled leaves and were more effective than nicotine sulfate and a combination of soluble and insoluble nicotine. Three and four applications were generally more effective than 1 or 2 treatments, and this is significant because the trees receiving 3 and 4 sprays were nearer the most heavily infested unsprayed trees.

During the spraying for the second generation, the infestation on the unsprayed trees increased to 69 percent, and the infestation in the sprayed trees increased correspondingly. Summer oil emulsion gave the best protection in this series with 17 percent infested tips, and the combination nicotine with 31 percent infested tips was the least effective.

Adaptability of Cryptolaemus to Control of Mealybugs in the Greenhouse. (W. D. Whitcomb and William Garland, Waltham.) Attempts to hold over the mature larvae and pupae of Cryptolaemus in cold storage have continued to be unsuccessful. In a room maintained at 45° F. for the cooling of cut flowers, none of the 400 full-grown larvae or 200 pupae survived a storage period of 2 months. When other larvae and pupae were stored in a typical cold storage room at 30°–33° F., none survived exposures of 1 to 3 months. At 45° F. it appeared that the low temperature retarded but did not stop the activity and permitted a partial development which results in death when continued.

Life history studies of the citrus mealybug continued to show that activity is retarded by exposure to constant temperatures between 60° and 65° F., but that development continues at a greater and more nearly normal rate at these temperatures than does the development of Cryptolaemus or many other greenhouse insects.

When Cryptolaemus were confined in constant temperature cabinets, the greatest activity and fastest development were at 80° F., but the average life of the beetles was 7.2 days longer at 70°. A temperature of 70° was also more favorable for the incubation of eggs, for larvae hatched from 49.7 percent of them at 70° and from only 34.3 percent of those confined at 80°. The average length of life of the larvae was 59.4 days at 70°, and 53.5 days at 80°.

At 60° F. no Cryptolaemus larvae have been reared from hatching to pupation, the average life being 28.83 days, and they ate only 2.36 mealybug eggs per day during that period. The feeding of the larvae at 70° and 80° was very nearly equal, being only 1.4 eggs per day greater at the higher temperature. The most active period of the larvae began after they had lived 20 days, when they ate more than three times as many mealybug eggs per day as during the first 20 days of their life. Just before pupation and before each moult feeding decreased, especially at 80° F.

A summary of these records follows:

Temperature (Fahr.)	Number of Larvae	Average Length of Life Days	Average Number of Mealybug Eggs Eaten per Day			
			Total Life	1st to 20th Day	21st to 40th Day	41st Day to to Pupation
60°	6	28.83	2.36	1.90	3.39	—*
70°	5	59.40	23.55	9.08	30.39	31.41
80°	6	53.50	24.92	11.55	35.50	27.84

*None lived over 40 days.

Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb, Waltham.) The greater part of the experimental work in 1936 was done with some of the commercial fumigants now available which have a naphthalene or benzene base.

These fumigants do not recrystallize at the lower greenhouse temperatures as does naphthalene and consequently can be used at any temperature suitable for growing plants. It was found, however, that it was necessary to maintain temperatures above 70° F. in order to obtain a satisfactory kill of the red spider mite, and that a greater mortality resulted when the relative humidity was 75 percent or higher. These facts were brought out by fumigations with one of the commercial materials at a dosage of ½ ounce per 1,000 cubic feet for 6 hours.

Temperature	Relative Humidity Percent	Mortality of Red Spiders, Percent	
		1st Fumigation	2nd Fumigation
85° F. (high)	75 (high normal)	98.10	100.00
75° F. (high normal)	75 (high normal)	78.99	100.00
75° F. (high normal)	55 (low)	59.68	94.72
60° F. (low)	75 (high normal)	22.11	66.38

Some of these commercial materials have undergone considerable experimenting in the past year, generally to correct a tendency toward bleaching of pink flowers, especially carnations. The changes have generally been made by sacrificing some of the effectiveness against red spider. Comparative fumigations at a dosage of ½ ounce per 1000 cubic feet for 6 hours under approximately uniform temperature and relative humidity resulted as follows:

Material	Sample	Mortality of Red Spider, Percent	
		One fumigation	Two fumigations
Commercial A	1	81.95	100.00
	2	78.99	100.00
	3	14.1	89.65
	4	56.41	98.02
Commercial B	12	99.17	
	3	17.23	68.59
	8	10.61	
Commercial C	1	74.36	97.19
	2	66.00	96.66

Experimental fumigations with these materials indicate that under reasonably normal conditions they should give very satisfactory control of the red spider mite, especially on carnations.

Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) In 1936 about 25 percent of the hibernating plum curculio beetles had entered the trees by May 15 when the calyx spray was applied. In comparison with past records, this number is considerably greater than normal, and in seasons when it occurs the value of a thorough petal-fall spray containing lead arsenate for combating the plum curculio in apples is greatly increased.

Normal curculio activity in 1936 extended from May 20 to June 10, and the critical periods were marked by the warm weather of May 23 to 25 and June 1 to 4.

In the experimental orchard only the McIntosh trees had a uniform crop of fruit, and the results are reported for that variety.

Six experimental sprays for timeliness of application, using lead arsenate and fish oil, were made at 3-day intervals from May 20 to June 4. The most effective treatment was that applied on May 23 just *before* the maximum activity of the first critical period. This date is two weeks earlier than the most timely application in 1935. The least effective applications were those made on May 26 and June 4 just *after* the increased activity on May 24 and June 2.

The crop of Gravenstein, Baldwin, and Wealthy apples in the experimental orchard was very small and scattered so that reliable deductions could not be made, but it was evident that an application for controlling the plum curculio which is timely on one of these varieties may not be timely and effective on another variety.

In the experimental spraying a soluble fish-oil spray, composed of 1 part of soluble fish oil which increased the mixing and spreading, and 3 parts of regular fish oil which maintained good adherence of the spray, was used with very satisfactory results.

Control of Red Spider. (W. D. Whitcomb, Waltham.) Further studies of pyrethrum and derris extracts as used in commercial sprays showed that the red spider mite is not satisfactorily controlled by pyrethrum extracts but that extracts of derris, either as rotenone or as other extracted resins principally deguelin, tephrosin, and toxicarol, gave satisfactory control in the proper concentrations.

In these tests the emulsified extracts containing 10 percent sulfated alcohol as a wetting and spreading agent were diluted 1-200 for application. A spray containing 1½ percent pyrethrins had practically no effect on the red spider and when the pyrethrins were increased to 2 percent, a relatively high concentration, the mortality was only 9.52 percent. The addition of ½ percent rotenone to the 1½ percent pyrethrins killed 37 percent of the red spiders, which is poor control but indicates an increased toxicity of 35 percent due to the rotenone. One percent pyrethrins and 1 percent rotenone combined averaged 79.65 percent mortality; and 2 percent rotenone without pyrethrins killed 87.16 percent of the red spiders and was the most effective formula used in this series.

Spray mixtures containing "other extracted resins" of derris were approximately one half as toxic to red spider as rotenone, and when used at twice the concentration produced an equal or slightly greater mortality of this pest.

A summary of the results is as follows:

Percentage of Pyrethrins	Percentage of Rotenone	Percentage of Other Derris Resins	Average Mortality of Red Spider Percent
1.5	None	1.0	62.24
1.0	None	2.0	84.25
None	None	4.0	86.77
1.5	None	None	1.81
2.0	None	None	9.52
1.5	0.5	None	37.09
1.0	1.0	None	79.65
None	2.0	None	87.16

Biology and Control of Carrot Rust Fly. (W. D. Whitcomb, Waltham.) The field infestation of the carrot rust fly was again light throughout eastern Massachusetts, and the only serious injury reported was in a planting of early carrots where heavy overhead irrigation was used during the oviposition period of the first generation.

Protection from first-generation injury by seed treatment was again very effectively accomplished at Waltham where the infestation was very light. Pure calomel and calomel diluted 1:3 with clay both gave almost perfect protection, and there was no significant difference between the regular grade of calomel and a special fine grade.

The field infestation by the second generation at Waltham was about 11 percent. One application of naphthalene flakes at the rate of 1 pound to each 100 feet of row gave no protection, but continued applications at weekly intervals gave increasingly better protection. From these records, it appeared that three applications at weekly intervals beginning about July 28 were advisable, but that the additional protection from four to five applications was not necessary.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920 Chapter 94)
Seed Control (General Laws, 1927 Chapter 94)
Dairy Law (General Laws, 1920 Chapter 94)
Advanced Registry Testing
Miscellaneous Work

Feed Control. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski, F. A. McLaughlin, J. T. Howard.) During the fiscal year 1,801 samples of feeding stuffs were officially collected and examined in the control laboratories. The gross receipts from the registration of feedings stuffs in 1936 (calendar year) were $22,480, derived from 1,124 brands at $20 each.

Seed Control. (P. H. Smith, F. A. McLaughlin, Olive M. Hoefle.) From October 1, 1935, to October 1, 1936, the Seed Laboratory analyzed 1,642 samples of seed, of which 850 were collected by the State Commissioner of Agriculture and 589 sent in by dealers and farmers. Tests for viability were also made on 203 ingredients found in 43 Special Mixtures.

Classification of these analyses is shown by the following summary:

	Official Samples	Non-official Samples	Totals
Purity analysis only	147	50	197
Purity and Germination	161	165	326
Laboratory germination only	542	374	916
Laboratory germination of Special Mixtures*	203		203
			1,642

*Samples germinated as a check on the quality of seed contained in 43 official samples which, by law, require only the statement of purity.

Field tests to determine trueness to type were conducted in cooperation with the Departments of Vegetable Gardening and Floriculture, the former testing 150 samples of vegetable seed and the latter, 104 samples of flower seed. All samples for these tests were collected and submitted by the State Commissioner of Agriculture.

The Seed Laboratory continued its practice of cleaning tobacco seed for farmers and instituted the new service of cleaning onion seed.

Dairy Law. (P. H. Smith, J. T. Howard, H. L. Allen.) During the year ending December 1, 1936, 7,163 pieces of Babcock glassware were tested; 111 certificates of proficiency were awarded; and 222 creameries, milk depots, and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, three machines were condemned.

Advanced Registry Testing. (P. H. Smith.) Advanced registry testing has been supervised by this department since its beginning in 1902. There are now on yearly test 333 cows located on 40 different farms. This does not include the herd tests where all animals in each herd are placed on test. There are 35 of these, 3 of which are supervised by men sent out from this office and 32 by cow-test association supervisors.

Miscellaneous Work. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski.) Numerous analyses have been made for residents of the State and other departments of the college.

Summary of Miscellaneous Work, 1936

Materials sent in:	
Milk and cream, butterfat only	545
Ice cream, for fat	75
Feeds, from farmers and dealers	119
Feeds, from State Institutions	124
For other departments of Experiment State and College:	
Dry matter, forage crops	281
Complete fodder analyses	100
Fat and fiber: Fruit, Vegetables and Feed Stuffs	125

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, J. W. Kuzmeski, A. F. Spelman, Chemists; J. T. Howard, C. L. Whiting, G. E. Taylor, Sampling Agents; Harry L. Allen, Laboratory Assistant.) Records for the year show that 112 firms have registered for sale in the State of Massachusetts 490 brands of mixed fertilizer and fertilizing materials and 52 brands of agricultural lime and gypsum. Results of analysis show that 75 percent of the mixed fertilizer brands, 83 percent of the unmixed fertilizer brands and 79 percent of the lime brands showed no deficiencies. The gross receipts from the registration of the fertilizer and lime products and from fertilizer tonnage fees for the year 1936 were $14,464.75.

For about ten weeks, beginning April 1, three experienced men employed to draw samples for inspection purposes sampled 21,132 sacks or containers, representing 14,789 tons of materials; 158 towns were visited, and 1,782 samples representing 532 brands were drawn from stocks found in the possession of 606 agents or owners. The following summary shows the character of these substances, as well as statistics with reference to their inspection.

	Brands Registered	Brands Collected	Samples Drawn	Number of Analyses	Number of Determinations
Mixed fertilizers	290	296	970	415	5,931
Ground bone, tankage and fish	48	50	161	64	486
Nitrogen products, mineral and organic	56	51	208	117	397
Phosphoric acid products	22	24	112	30	127
Potash products	23	23	72	31	100
Dried pulverized natural manures	29	30	88	34	217
Nitrate of potash	7	7	19	11	62
Peat products	2	4	7	4	21
Wood and cotton hull ashes	6	4	8	8	57
Miscellaneous	5	5	14	6	51
Lime products	51	51	115	56	634
Totals	539	545	1,774	776	8,083

During the period July 1, 1935 to July 1, 1936, the tonnage of fertilizer and plant food sold in Massachusetts was as follows:

		Plant Food Elements (Tons)		
	Fertilizer (Tons)	Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	43,682	2,238	3,727	3,097
Unmixed fertilizer chemicals and materials	19,165	1,386	1,667	672
Pulverized natural manures	1,634	35	25	47
Totals	64,481	3,659	5,419	3,816

Full details of the fertilizer and lime inspection will be found in Control Bulletins 84 and 87.

Miscellaneous Analytical and Diagnostic Work. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski.) Chemical studies of a cooperative nature have been carried on, as has been the custom in the past, with the several departments of the institution, Field Station, and County Agents. The character and extent of this work is shown in the following summary:

Apple tree leaves	27	Lime compounds	1
Apple spray residue	32	Miscellaneous	3
Blueberries	3	Nicotine solutions	4
"D" deficient diets	7	Poultry manure	41
Fertilizers	24	Synthetic manures	7
Field crops	160	Sewage sludge	3
Gardenia stems	2	Turnips	4
Gardenia leaves	2	Weed exterminators	4
Insecticide solutions	4		
Total			328

Other chemical work of the department has included service to community organizations, State institutions, and individuals interested in agriculture. This group includes the following materials:

Animal tissues for mineral poison	5	Lime products	6
Apple spray residue	5	Miscellaneous	2
Ashes of various kinds	3	Peat products	9
Compost	2	Sheep manure	7
Fertilizers and fertilizer chemicals	26	Sheep manure and wool waste	10
Insecticides	2	Soils	13
Industrial by-products	8		
Total			98

Research work in cooperation with the Association of Official Agricultural Chemists of North America has included methods for the determination of soluble and available magnesium in mixed fertilizers and the determination of the acidity and alkalinity of mixed fertilizers. Services of an executive and advisory nature have also been rendered to this organization as in the past.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) Rust-resistant varieties of snapdragons sold by various seed firms showed a relatively high degree of resistance to rust under greenhouse and field tests at Waltham. The Field Station rust-resistant strains continued to show satisfactory performance under greenhouse and field conditions. The resistant yellow-flowered strain tested by several commercial growers under glass last year proved so satisfactory that requests for more seed were granted to those growers who wished to make further trials.

Field Station strains crossed with the resistant commercial varieties yielded progeny carrying a high degree of resistance to rust. No physiologic strains of the rust *Puccinia antirrhini* have been observed at Waltham. Field Station resistant strains were inoculated with cultural rust material obtained from California but there was no evidence of infection whereas commercial varieties, inoculated with the rust, became infected.

Data on the susceptibility of inbred and hybridized strains to *Verticillium* wilt in the field indicate that a double type of resistance to rust and wilt may be eventually obtained. Commercial varieties were 100 percent susceptible to wilt as compared to 20 to 80 percent resistance in the case of hybridized strains. Those strains that are most susceptible to rust appear to be less resistant to *Verticillium* wilt.

Study of the Effect of Plant Nutrients, Soil Reaction, and Light on Gardenias. (Harold E. White, Waltham.) Chlorosis of gardenias, which occurs in varying degrees wherever the plants are grown under glass, was found to be due to improper assimilation of iron. A chemical analysis of normal and chlorotic plants and inoculation tests with different chemical elements proved to be a satisfactory means of determining iron deficiency in gardenias.

The use of sulfur in small quantities and the use of organic or ammonia sources of nitrogen were effective in preventing iron chlorosis. Plants severely affected with chlorosis made very poor response to treatments with iron compounds or soil amendments, and in some cases plants so affected never became normal.

Soil reaction alone was not a satisfactory means of determining whether or not a particular soil was adapted to gardenia culture.

Data for the past two years are being assembled for publication as a bulletin at an early date.

Propagation Studies on Gardenias. (Harold E. White, Waltham.) Propagation technique and various chemical treatments do not appear to be of much importance in the rooting of cuttings of gardenias. Soft-wood cuttings rooted as readily as more mature wood. Cuttings taken from chlorotic plants do not form as vigorous root systems as cuttings taken from normal plants. Correct humidity and temperature in the propagating house were of primary importance in successful rooting of gardenia cuttings.

Since gardenias can be successfully grafted, this method of propagation might be used to control nematode disease if a disease-free rootstock could be found.

Propagation Studies on Geraniums. (Harold E. White, Waltham.) The varieties S. A. Nutt, Alphonse Ricard, and Beaute Poitevine were used in this experiment. The maturity of cutting material, time of propagation, location of cuts on cuttings, type of media, chemical dips, and sterilized sand, did not appear to have any beneficial effect on the rooting of geranium cuttings. Stem rot, or black rot as it is sometimes called, would seem to be the limiting factor in successful propagation of geraniums since none of the various cultural methods appreciably affected rooting. Also, the rot was extremely virulent even with variation in conditions and technique.

This past year cuttings from plants sprayed with Bordeaux in the field were compared with cuttings from unsprayed field plants. It was reasoned that if infection occurred in the field, spraying should give some appreciable control. Spraying in the field did not reduce the percentage of loss of cuttings from the rot disease. The percentage of rooting of cuttings from sprayed and unsprayed plants is tabulated below:

Variety	Media	Percentage Rooted Unsprayed	 Sprayed with Bordeaux
S. A. Nutt	Sand	59	14
S. A. Nutt	Sand and peat*	52	52
Alphonse Ricard	Sand	71	36
Alphonse Ricard	Sand and peat*	74	51
Beaute Poitevine	Sand	56	29
Beaute Poitevine	Sand and peat*	68	49

*In the proportion of 4 parts of sand to 1 part of peat.

Carnation Fertilizer Experiments. (Harold E. White, Waltham.) Preliminary cooperative fertilizer studies are being carried on with nine carnation growers in Massachusetts. This type of experimental setup is worthy of note inasmuch as most of the fertilizer experimental work reported by institutions doing work in Floriculture has been conducted on small plots at the stations on one particular soil type. This work was inaugurated by a research committee composed of growers appointed by the New England Carnation Growers' Association to work with the Experiment Station.

The growers expressed an opinion that specific or general recommendations as to fertilizer applications to carnation soils in Massachusetts can be made more satisfactorily by conducting studies on their own soil types and under commercial growing conditions, rather than on one soil type and with small plots as at the Experiment Station. A total of 1800 square feet of bench space of carnations is under observation in nine ranges of glass, with 200 square feet of space being devoted to this purpose by each grower. The ranges chosen have been selected with due regard to possible variation in weather conditions and soil types.

The work has not been in progress long enough to permit accumulation of much data except results of physical and chemical analyses of field or compost soils before any fertilizers were applied.

The soil pH determinations were made with a potentiometer equipped with a quinhydrone electrode. Tests for nutrient elements were made with the Morgan micro-chemical or quick-test methods, with due care being given to interpretation of the results.

The micro-chemical tests for nutrient elements are accepted by many workers as a means of determining the relative levels of reserve plant food elements in soil on the basis of being adequate or inadequate for normal plant growth. A possible explanation of the reason why many of the soils appear to be uniform in content of nutrients while having no apparent similarity in origin may be the fact that the tests were originally designed on the basis of field soil fertility and not calibrated for the higher nutrient levels as they exist under greenhouse conditions. That is, the maximum and minimum levels as established by the tests for field conditions do not hold true for greenhouse soils. These micro-chemical tests have been applied to the soils from the experimental plots with the purpose of determining whether or not the system is suitable for use under greenhouse conditions, and if so to establish approximate levels of fertility on the basis of these tests. Soil productivity with regard to plant-food elements can be evaluated only as potential reserves inasmuch as other environmental conditions are limiting factors.

Horticultural Schools. (Harold E. White, Waltham.) This year a departure was made from our usual method of conducting the Home Gardeners' School lectures by distributing the lectures through the month of April, instead of having a two-day program. Each lecture was held in the afternoon from 1:30 to 4:30. The reasons for this change were to allow more time for personal and general questions on the topics discussed and to associate the program more closely with the College by using our small meeting hall in place of the large hall at Cedar Hill. The response to the program was more than satisfying in that the registration was so great that it was necessary to repeat four of the seven lectures, making a total of eleven lectures given. The registration surpassed our 1931 record of 700 by increasing to 1166 for the series of 1936.

There were 217 florists in attendance at the Florists' School held on February 18 and 19 at the Waltham Field Station.

The registration figures and interest of the general public in these schools indicate that they are worthy of the financial support given them by the College.

DEPARTMENT OF HOME ECONOMICS

Helen S. Mitchell in Charge

Cause and Control of Nutritional Cataract. (H. S. Mitchell and G. M. Cook.) The production of nutritional cataract in rats fed on lactose or galactose rations has been previously demonstrated. Further studies in this field have been reported or are at present in progress.

1. *Susceptibility of different strains of rats to nutritional cataract.* A report of these findings was made at the American Home Economics meeting in Seattle, Washington, July 7, 1936, and was published in the *Journal of Nutrition 12:* 447–453, 1936. Rats from different colonies showed variable susceptibility to cataract. The Battle Creek strain had the highest incidence and the mature cataracts developed in the shortest time of any of the three breeds tested on the 70 percent lactose ration. The Massachusetts State College and the Wistar strains showed advanced lens changes but complete opacities developed in only 10 and 9 percent, respectively, of the rats tested. On the 35 percent galactose rations the incidence of mature bilateral cataract was 100 percent in the Battle Creek and Massachusetts State College strains and slightly less in Wistar and Johns Hopkins strains. The time for cataract to develop was shortest in the Battle Creek strain. Severity of intestinal disturbances did not correlate with cataractous changes in the lens. Growth was normal on the galactose but slightly retarded on the lactose ration, probably due to the persistent diarrhea in the young rats. Cataract development was more rapid in young rats than in older ones. The age at which animals are started on experimental rations must be kept constant if results are to be consistent.

2. *The relation of ingested carbohydrate to the type and amount of blood and urine sugar and to the incidence of cataract in rats.* The report of this work has been accepted for publication in the *Journal of Nutrition* early in 1937. Blood and urine sugar studies have been made on rats fed on adequate rations containing 62 and 70 percent lactose, 25 and 35 percent galactose, 35 percent fructose, 35 percent xylose, and 70 percent starch. Determinations of total and nonfermentable sugar were made on both blood and urine specimens from the various ration groups. Total blood-sugar values were higher on galactose rations than on lactose but above normal in all animals on cataract-producing rations. The nonfermentable fraction of blood sugar was the variable in the different groups, the fermentable fraction remaining more nearly constant and within the range of normal blood glucose. Average total blood-sugar values of three strains of rats fed on the 35 percent galactose ration were strikingly similar, in contrast to the differences observed in susceptibility to cataract among the same groups. Insulin-protamin (Lilly) failed to lower blood galactose or reduce the speed of cataract development on a 25 percent galactose ration. Galactose is chiefly responsible for both the high blood and urine sugars observed in rats fed on lactose and galactose rations and must be the major etiological factor in this type of cataract.

3. *Effect of other dietary variations on susceptibility to cataract.* The cataract-producing action of lactose or galactose rations containing variable types and amounts of other ingredients has been investigated. Work is still in progress on the effect of fat content of the diet. So far the carbohydrate type and amount is the crucial factor.

A Study of the Nutrition of College Women with Respect to Vitamin C Requirements. (H. S. Mitchell and O. A. Merriam.) This project was initiated in October 1936 and is concerned with the vitamin C intake and excretion of eighty freshmen women as related to their general nutritional condition. Vitamin C has been made the point of attack because of the tendency for college students to reduce expenses, if necessary, by curtailment in the purchase of fresh foods. The Department of Horticultural Manufactures which has been interested for years in the vitamin C content of foodstuffs has offered to assist and may cooperate in certain phases of this project. If results warrant it, this project may continue for a period of 2 or 3 years in order to obtain information on the same students over a period of time.

A Study of the Source and Amount of Iodine Effective in the Prevention of the Pathology Produced in Rabbits and Guinea Pigs by Feeding Cholesterol. (H. S. Mitchell and M. Goldfaden.) This research is being sponsored by the Lang Fund. Findings to date are entirely preliminary and incomplete. One group of guinea pigs fed on cholesterol with and without supplements of iodine in three different forms has been autopsied and various tissues saved for histological study. There was extensive gross pathology of liver and spleen in cholesterol-fed animals with some slight indication of lesser pathological changes in those animals which had received certain iodine supplements. Blood vessel changes were not prominent but some thickening and loss of elasticity of the aorta was evident in certain animals. A group of twenty-four rabbits is now being fed cholesterol with and without various sources of iodine. The growth and general condition of the rabbits is apparently satisfactory but autopsies, which are the final criteria, will not be made until later. It is impossible to give even preliminary conclusions at the present time, but the approach to the problem appears to be promising and worthy of continued and more extensive investigation.

Use of Banana and Milk in Diets for Weight Control. (G. M. Cook.) Work on this project was completed in June 1936 and the complete report in the form of a thesis was sent to the United Fruit Company who sponsored this project. The thirteen college students who participated in the study not only aided in making a scientific contribution but also personally benefited from the experience.

The dietary regime was as follows: One half pint of whole milk and two bananas or other fruits in amounts equivalent in caloric value were served for breakfast and lunch, while a well-balanced dinner of restricted caloric value was served at night. The daily caloric intake ranged between 1,200 and 1,300 calories. The average weight loss ranged from 1.25 to 3.8 pounds per week. Of the thirteen subjects, seven found the satiety value of the banana regime to be greater than that of other fruits; four students noticed no difference; one would not express an opinion; one considered variety more satisfying than the monotony of the banana regime.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Technological and Nutritional Investigations on New England Apples and Apple Products. (C. R. Fellers, J. A. Clague, and A. S. Levine.) Research on cider and cider products has progressed to the point where a bulletin on the subject has been published (No. 336).

The study of the suitability of important Massachusetts varieties of apples for baking, sauce, pie, and cider manufacture has been continued using Baldwin, King, Northern Spy, Roxbury Russet, McIntosh, Cortland, Ben Davis, Rome, Rhode Island Greening and Jonathan varieties.

Using human subjects, a study is under way to ascertain the effect of eating apples on urinary acidity and blood alkali reserve. Preliminary results with McIntosh apples show that the apple does not affect the acidity of the urine or lower the blood alkali reserve. Baldwin apples are now being used in similar controlled feeding experiments on young men.

Successful canning of oven-baked apples has been accomplished in this laboratory. The best varieties for this purpose are Jonathan, Rome, York Imperial, and King. The fruit should be firm and sound for baking. The cores are removed and the skins scored before placing in the oven. After cooling, the baked apples are packed into cans with a 50 percent sugar sirup and finally processed for 30 minutes at 212° F. This is an excellent product and one which should prove very popular.

Progress has been made on the development of a simple yet effective and inexpensive method of preparing an apple pectin concentrate for home use in jam and jelly making. This investigation includes a study of extraction and clarification methods of apple pectin and its concentration and preservation for home use. Many farmers grow their own apples and it is believed that an inexpensive method of extracting pectin from the fruit will be welcomed.

Mr. Julius Novick, a graduate student, has done creditable work in the preparation of apple table sirups. Some of these products are of good quality, clear, palatable, and of good flavor. In order to keep a light color the *p*H of the sirup must be kept slightly acid. Most of the malic acid is precipitated out by the use of lime.

Nutritive Value of Frozen Foods. (C. R. Fellers, C. F. Dunker, and D. DeFelice.) Sweet corn at the eating stage contains approximately 40–50 units of vitamin C per ounce and is, therefore, a fairly good source of this vitamin. Furthermore, the vitamin C in sweet corn is very stable and little is lost either on storage in the husk for two days or on cooking. Sweet corn may be quick-frozen, either on the cob or as whole-grain kernels with very little loss of vitamin C. Canned whole-grain sweet corn retains its antiscorbutic activity to a greater degree than canned cream-style sweet corn. Canned lye-hominy contained very little vitamin C. A paper covering this study is now in press (*Food Research* 2: No. 1. 1937).

Lima beans may lose 30 percent of their vitamin C after picking and during shipment to market. When quick-frozen, fresh lima beans retain their vitamin C very well. The principal loss occurs during the blanching process. Lima beans lose a considerable amount of vitamin C during the canning process. Freshly picked lima beans contain 500 units per ounce and are an excellent antiscorbutic. The mature beans contain only traces of vitamin C.

The results of the investigation on frozen peas are published (*Amer. Soc.*

Hort. Sci. Proc. 33: 627–633. 1936). At the present time a second season's work on spinach is under way. Raw spinach loses considerable amounts of vitamin C in cooking and in the processes incidental to freezing and canning. Thus, fresh spinach containing 400 units per ounce is reduced to 250 after cooking and to approximately 100–150 units in the cooked frozen spinach. The vitamin A of spinach is well retained after freezing or canning.

Blueberries. (Oreana Merriam and C. R. Fellers.) A paper has just been published (*Food Research* 1: 501–512. 1936) on chemical and nutritive studies on blueberries. Both *Vaccinium corymbosum* and *V. pennsylvanicum* were used, as well as several cultivated varieties. No marked differences in composition or content of vitamins A and C were found. Freezing the fruit had no effect on these vitamins. Some of the canned blueberries showed good retention of vitamin C. Blueberries are fair antiscorbutics. The average vitamin C content is from 1 to 2 units per gram. The vitamin A content is low, e.g., 0.2 international unit per gram.

When blueberries were fed to normal young men no increase in urinary acidity or lowering of the blood alkali reserve occurred. Only traces of benzoic acid could be obtained from blueberries.

Work is in progress on methods for the manufacture of blueberry cordial and other products.

Tomatoes and Tomato Juice as Antiscorbutics. (W. A. Maclinn, C. R. Fellers, and R. E. Buck.) In cooperation with the Department of Olericulture, 98 distinct varieties and strains of tomatoes were grown on the campus plots. Six fruits of each variety were examined for ascorbic acid content (vitamin C) by the chemical method. Earlier work had shown that results obtained by the 2, 6-dichlorophenolindophenol dye titration method agreed well with the results obtained by the standard guinea pig bioassay. Marked variations, from 75 to 250 units per ounce, were observed. Richest of all tomato strains tested, were new Waltham Field Station crosses and selections. Marglobe and Stone varieties were good carriers of vitamin C, but Rutgers and Pritchard were relatively poor. No losses in vitamin C occurred during storage so long as the fruits remained sound and firm. Similarly, degree of maturity had no effect, as partly green tomatoes contained as much vitamin C as fully ripe fruits.

Tomatoes lose 50 percent or more of their original vitamin C in the process of manufacture into juice. The factors responsible for this loss are being studied experimentally. Some of the results of this investigation are in press in *Amer. Soc. Hort. Sci. Proc.* 1936.

Home Canning Research. (C. R. Fellers, W. A. Maclinn, and A. S. Levine.) The results of these investations insofar as pressure-vacuum relationships in the jar are concerned have been prepared for publication. However, many data on oven-canning have been collected and will be made public in bulletin form during the year. On the whole, oven canning is a dangerous and unsafe method of food preservation.

Another year's experience with cooperators throughout the State has demonstrated the utility and soundness of the new method of processing glass jars with the lids firmly clamped down. Less liquid is lost during processing and the appearance of contents of the jars is greatly improved. There is also a saving of time and less danger of getting burned while clamping down the wire bails while the jars are still very hot. Breakage of jars is not increased by the use of this method. It can be fully recommended for use by home canners.

Vitamin D Investigations. (Wm. B. Esselen, Jr. and C. R. Fellers.) The survey of the various methods of incorporating vitamin D in market milk has been continued. Numerous samples of irradiated, fortified (cod liver oil), and metabolized (yeast) milks have been assayed for their content of vitamin D. In general, the dealers' guarantees as to amounts of this vitamin present per quart are in accordance with the facts. Consumers of vitamin D milk in Massachusetts may be reasonably certain that the milk they purchase actually contains vitamin D in therapeutic quantities.

A number of cod liver oils, poultry feeds, and miscellaneous food and feed products have been assayed for vitamins A, D, and G. There is an increasing interest in the vitamin content of human foods and animal feeds.

Bulletin 338 is in press dealing with the stability of the vitamins in fruits and vegetables subjected to storage, freezing, drying, and canning. This bulletin collates much scattered materal in the literature and brings the subject up to date.

Nutritive and Technological Studies on Fishery Products. (C. R Fellers, J. A. Clague, and D. A. Bean.) The Atlantic Whiting (*Merluccius bilinearis*), a marine fish of great abundance in Massachusetts waters, was examined chemically for food value and also with a view to better utilization in new products. Various experimental packs of canned, salted, kippered whiting as well as chowder and fish flakes were made. The kippered (smoked) whiting is a delicious product worthy of commercial exploitation. Canned chowder and flakes were also very good products.

The whiting flesh possesses high nutritive value. The livers, which contain 30 to 42 percent oil, assayed 2700 units of vitamin A and 200 U.S.P. units of vitamin D per gram. These values are here reported for the first time.

A paper was published (*Trans. Am. Fish. Soc.* 65: 342–349. 1935) on the nutritive value of the blue crab (*Callinectes sapidus*) and of the sand crab (*Platyonichus ocellatus*). A method for the successful preservation of the blue crab by canning has been perfected.

Fermentation Investigations. (C. R. Fellers, V. Jancik, and A. S. Levine.) The citron fermentation studies have been completed and published (*Jour. Agr. Research* 53 (11): 859–867. 1936). This paper also contains data on the chemical composition and vitamin A and C content of the citron.

Studies on the preservation of the red and green sweet peppers and melons by means of salting and fermentation have been under way for one season. The peppers are readily preserved by storing in a 15 percent salt brine. Watermelons and citron melons can also be preserved satisfactorily for later preserve and pickle manufacture, by either salting or brining. This study will be continued.

Another season's work shows that the addition of 1 percent dextrose to dill pickles before fermentation accelerates the fermentation, insures a clean, lactic bacterial flora, and increases the final acidity of the cucumber pickle over the control lots.

Dog Foods. (J. Bernotavicz, C. R. Fellers, and W. S. Ritchie.) The development of a nutritionally complete canned dog food has been initiated. A number of springer spaniel pups are being used in feeding experiments. The possibility of using dried buttermilk as the principal source of protein in this food is being studied.

Crushed Fruits and Syrups. (K. Newman, C. R. Fellers, and M. J. Mack.) This study is concerned with the use of preserved crushed fruits such as strawberries, pineapple, peaches, etc., in frozen desserts. Chocolate syrups are also included. These crushed fruits and syrups are made with varying ratios of sucrose and dextrose in an effort to determine whether or not a part of the sucrose may be replaced with purified corn sugar (dextrose). Very satisfactory crushed fruits, syrups, ice creams, and ices have been prepared using as much as 50 percent dextrose. In most products, however, smaller quantities of dextrose are more desirable.

Cranberry Investigation. (C. R. Fellers, J. A. Clague, Wm. B. Esselen, Jr., and A. S. Levine.) Continued work has been in progress on cranberry sauce manufacture, cranberry cordial, and cranberry juice. A superior quality of cranberry juice was made by grinding the raw cranberries, allowing them to set for 1 or 2 days, and pressing in a hydraulic press. To be palatable, the pure juice was diluted with 1½ to 2 parts of water and made up to a sugar content of 15 to 20 percent. The bottled juice is readily pasteurized by heating to 150° F. for 25 minutes.

A very attractive, distinctive cordial was prepared by adding to the fresh-pressed juice, pure alcohol and sugar. The optimum alcohol content ranged from 25 to 40 percent by volume and the sugar content from 25 to 35 percent. Material is being collected for a bulletin on the subject of cranberry products.

Cooperative cranberry storage investigations with Professor C. I. Gunness of the Rural Engineering Department and Dr. H. J. Franklin of the Cranberry Experiment Station at East Wareham, have been in progress since September, 1936. Various types of storage and storage temperatures were used. This department has made gas analyses (CO_2:O_2 ratios) on all samples. This project will be continued.

The Influence of Iodine and Vitamin D on Scurvy in Guinea Pigs. (W. B. Esselen, Jr., and C. R. Fellers.) It has been thought by certain investigators that mild scurvy may be a precursor to certain forms of arthritis. For some time iodine has been used clinically in the treatment of arthritis. In view of this hypothesis, work has been carried on to ascertain whether or not iodine treatment is of value as either a curative or a preventive of scurvy in guinea pigs. Iodine was administered to guinea pigs with mild scurvy, in the forms of iodized milk and kelp. There is no indication that these iodine supplements are of any value in either curing or preventing scurvy in guinea pigs. The animals receiving the iodine supplements lived no longer than control animals receiving no iodine and showed the same degree of scurvy. Individual growth curves for each guinea pig were made. There was no evidence that the animals receiving iodine lost weight at a lower rate than the controls. Similarly, there were no differences noted at autopsy among the various experimental animals in the location of, or in the severity of the scurvy lesions. It is concluded that iodine therapy has no beneficial effect in preventing or curing scurvy in guinea pigs.

In both rickets and scurvy an enlargement of the leg and costochondral joints occurs. It is thought that this condition in scurvy may possibly develop as a consequence of a disturbance in the normal vitamin D and mineral metabolism. An investigation is under way to study the effect of large doses of vitamin D on the enlargement of the joints in scorbutic guinea pigs.

Effect of Variety and Stage of Growth on Vitamin A, C, and D Content of Maize. (Wm. B. Esselen, Jr., Benj. Isgur, and C. R. Fellers.) In the growing maize plant, white dent varieties contained as much vitamin A as yellow dent. In the mature grain of the white dent, no vitamin A was found. Vitamin C was practically constant for all varieties but decreased with increasing maturity of the plant. Vitamin A increased as the maturity increased.

Green maize plants contain approximately 2 international units of vitamin D per gram, but this is rapidly lost on drying or storage.

DEPARTMENT OF HORTICULTURE

R. A. Van Meter in Charge

Tin Pots for Finishing and Shipping Hardy Plants. (George Graves, Waltham.) Behind this investigation lies the desire for a plant product of nominal production cost which will be not only more merchantable but also capable of giving greater cultural satisfaction. Because ample literature and precedent of west coast nurseries establish the feasibility of tin plant containers, study is being directed chiefly towards the mechanical and economic phases involved. For the moment, consideration is being limited to a tin container of suitable size (approximately one gallon) for the merchandising of roses and small shrubs in full growth.

Salvaged Cans. A gallon oyster pail, or a 3.6 quart food can may be converted into a suitable collapsible growing and shipping pot. This pot, which has all cuts necessary for drainage and final easy removal of the plant, can be made and coated with asphalt paint for a maximum average figure of 9 cents. This price is based on tests which started with dirty cans and carried out all operations with the crudest of tools, unskilled labor, and the most laborious of methods which gave no thought to straight-line production technique. Labor was figured at 50 cents per hour and 10 percent was added for overhead. Subsequent study has revealed that by simplification of design, elimination of hand brush painting or of painting altogether, and some semblance of production layout, this type of container could be produced at home for less than 5 cents. The limiting factor for large production will be found to be the doubtful source of supply of raw material.

New containers of special design manufactured expressly for the purpose have not yet received thorough study. At the present it does not appear that any adequate product at all suitable for the purpose can be manufactured by local companies for less than 8 cents, although there are reports of such a container of west coast manufacture which is priced much lower.

Study of Hardy Ornamental Material. (George Graves, Waltham.) This project took over all hardy species, chiefly of herbaceous plants, already growing on the Waltham Field Station grounds. This older material has been evaluated, relabeled, and given cultural attention. After having lost 18 sorts through death, discarded 112 others as obsolete or redundant, and made 634 accessions, the collection at the year's end numbered 1340 items.

All material is now catalogued. Every plant is cross-indexed on the basis of (1) Accession number, (2) Name, in accordance with the international code nomenclature, (3) Source and date of receipt, (4) Location. Other data carried have to do with (1) Final disposal, (2) Relative garden value, (3) Cultural history and requirements, and (4) Accuracy of Nomenclature.

Thus, the setup for testing herbaceous material is about complete. Limited space, prohibitive cost of maintenance, and proximity of the Arnold Arboretum, prevent and exclude indiscriminate field work with woody plants. Work with trees and shrubs must be confined almost entirely to individual experimental projects.

Approximately two hundred clons of Hemerocallis have been assembled for the purpose of study and evaluation during the next few seasons. This study is being started in the hope that out of the chaos now surrounding the garden forms of this genus will come some few superior selections.

A current sampling of opinion of prominent horticulturists, plant specialists, and landscape planters, is being made to determine, if possible, a basic list of woody plants for New England parks, gardens, and roadsides. This study has thus far turned up the following strong trends: (1) Increasing unpopularity of weeping trees and other similar garden monsters, (2) A greater interest in native plants (for instance, there are 70 varieties of *Tsuga canadensis* in cultivation), (3) The growing unpopularity of garden forms of *Chamaecyparis* and *Thuja*, (4) Intense dislike for plants having variegated leaves or yellow foliage, (5) Increased interest in woody plants for ground cover and rock garden, (6) Greater appreciation on the part of the planter of the bearing of ecological factors on satisfactory culture, (7) A growing interest in fastigiate trees other than *Populus nigra italica*, and (8) Realization that the term "hardy" as applied to a plant is most indefinite.

Clonal Apple Investigation. (George Graves, Waltham.) A new project. There are no results to report as yet.

To date East Malling stocks No. 1, 2, 4, 5, 9, 12, 13, 15, and 16 have been assembled in anticipation of getting investigation under way.

DEPARTMENT OF OLERICULTURE

Grant B. Snyder in Charge

Packet Seed Studies. (G. B. Snyder and A. P. Tuttle.) A large majority of home gardeners buy their vegetable seeds from the neighborhood store in either packet or bulk lots. It has been found that seeds purchased in this manner frequently have a variable germination and are not true to the name under which they are sold. In order to check these factors, state inspectors purchased some 150 lots from various stores in the State. These included ten of the more important vegetables: beans, beets, carrots, lettuce, onions, parsnips, radishes, spinach, squash, and turnips.

Field notes on germination indicated fair vitality in most lots. There was some variation in trueness to name of a few lots. Only one source, however, produced plants from every lot which were definitely off type and variable in maturity as well as disease susceptibility.

Systematic Studies of Turnips and Rutabagas. (G. B. Snyder.) Detailed plant and root records were taken of 15 lots (13 varieties) of rutabagas and 15 lots (15 varieties) of turnips. This is a cooperative project with the Federal Division of Fruit and Vegetable Crops and Diseases, and the data obtained will be used in the compilation of a Federal type book.

Systematic Studies of Vegetables. (A. P. Tuttle and G. B. Snyder.) During the past few years a large number of improved and new varieties of vegetables have been offered to the vegetable grower. Many of these newer sorts were planted in the trial plots along with the more standard sorts and comparatively evaluated for performance, quality, and adaptability to Massachusetts conditions. Some one thousand different lots covering more than 50 different kinds of vegetables were included in the trials. Detailed records were, however, taken on only lettuce, sweet corn, and tomatoes. In lettuce, New York No. 12 and No. 515 were outstanding in earliness, freedom from tip burn, and percentage of crop marketable. In tomatoes, the Field Station Comet, Bonny Best, and Marglobe gave the best results as trellis varieties. In general the hybrid varieties of sweet corn were later in maturity, of better quality, and produced a larger ear and plant than their respective standard varieties.

Asparagus Investigations. (Robert E. Young, Waltham.)

Varietal Improvement. The cutting records for the 278 individual asparagus plants indicate that the plants that were high producers in the past continued to be so classed this year. Seed collected last year from the high-yielding plants produced a fine crop of seedlings for transplanting in the spring of 1937.

Asparagus rust was present in the planting for the first time this year, thus affording an opportunity to eliminate from consideration as parental material all susceptible plants.

The results for the last three years indicate that the high-producing plants give visual indication of their potential production, thus enabling plant breeders and growers to select the proper plants for seed production without the necessity of keeping yield records.

Data covering certain phases of this work are being prepared for publication.

Depth of Planting and Height of Cutting. There has been no important change during the past year in this long-time experiment. The shallow-planted asparagus roots remain the highest producing plot in the depth-of-planting experiment. Shallow planting has not reduced the percentage of fancy asparagus produced.

Cutting asparagus with 12 inches of green has not weakened the plants.

When asparagus is cut with only 4 inches of green, there is a reduction in both total yield and percentage of fancy asparagus.

In this experiment to date cutting the asparagus with plenty of green on the spears, as the market demands, has not lessened the yield as most growers believed.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.)

Waltham Scarlet Shell Bean. Samples of the new Waltham Scarlet Shell Bean were again distributed to a large number of growers to obtain their reaction, and for comparison with other strains of beans on various types of soil and methods of culture. Replies from the growers indicate that this shell bean has merit and a definite advantage over other strains. Many growers, having used the samples of seed as stock seed, now have sufficient seed for all their planting. Several lots of seed for sale during 1937 were grown by those merchandising the new seed. The supply, however, is still far from sufficient.

Waltham Beauty Pepper. The results obtained during 1936 with the Waltham Beauty Pepper were a confirmation of those obtained in 1935. The trials by growers indicate that in most places the Waltham Beauty is quite satisfactory. Many growers reported that they received a higher price for this pepper than they did for any other varieties largely grown. This is mainly due to the desirable shape, making a pleasing market package. These peppers are also the proper shape for stuffing.

At least four seedsmen are offering a commercial supply of seed for sale in 1937.

The stock seed supply was replenished during the year by mass selection. All breeding work on peppers has been transferred to a Waltham Beauty hybrid to eliminate one or two objectionable features of the pepper. The data on the development and proper culture of the Waltham Beauty pepper are being prepared for publication.

Lettuce. During the past year work was started to produce a New York type of lettuce better acclimated to Massachusetts. This work was in cooperation with the Division of Fruit and Vegetable Crops and Diseases of the United States Department of Agriculture. Extensive plantings were made of some thirty strains and varieties of lettuce, one-third of which were hybrid material supplied by the cooperating agency. From this group approximately fifty plants were selected as having some promise, and will be grown next year for further trial.

The new selection of Bel-May lettuce for forcing was grown in commercial quantity during the year and judged to be superior to the old strain. To further improve certain characters in this lettuce, hybrids were made between it and an English variety. The F_1 generation was grown during the summer, and the F_2 generation is now in the greenhouse. The demand for greenhouse lettuce seed remains about the same as last year.

Tomatoes. Stock of the Waltham Forcing tomato was maintained during the year. The demand for this tomato from those merchandising it was approximately double that of a year ago, which would indicate that its popularity is spreading rapidly. Greenhouse trials with this and other greenhouse varieties from other sections indicate that the Waltham Forcing will set fruit under more adverse weather conditions than other varieties. Although this tomato has not been recommended for outside trellis use, many growers found it to be entirely satisfactory if given plenty of fertilizer and water during the growing season.

The hybrid tomato for trellis use which has been in the process of development for the past few years has been perfected to the stage where samples will be offered to growers during 1937.

Hutchinson Carrot. The stock seed of the Field Station strain of Hutchinson carrot was maintained and the supply replenished. Efforts to improve the color and core of this carrot are beginning to show results. The work of hybridization of the Hutchinson with other carrots of better color and core was undertaken again this season after loss of the material last season through rotting. The demand for the Field Station strain of Hutchinson carrot increased during the past year.

Wyman Crosby Beet. The Field Station strain of Wyman Crosby beet was further improved during the year although it has not yet reached the stage where it may be placed in the hands of the growers. The Field Station strain is uniform in shape and grows rapidly, but lacks sufficient uniformity of internal color to satisfy the market demands for beets.

Blue Hubbard Squash. During the past season comparisons have been made between selfed lines of Blue Hubbard squash and commercial strains and hybrids between each. There is evidence of considerable hybrid vigor in these strains, the highest yielding line being a hybrid of two selfed lines. Very satisfactory yields were obtained with hybrids from commercial and selfed lines. Progress has been made toward obtaining the type of squash the growers desire.

Cucurbita Pepo. Certain crosses in *Cucurbita Pepo* were made last year and when grown during 1936 indicated that the hard seed character is dominant over the soft seed character. It has not been determined whether this dominance is complete or partial, nor the genetical segregation. Crosses between golden straight neck and soft seeded parent give promise of producing a summer squash that contains seed of less prominence in the edible stage.

Trellis Tomato Experiments. (Robert E. Young, Paul W. Dempsey, and Harold A. Wilson, Waltham, and Alden Tuttle.) Preliminary studies in methods of producing trellis tomatoes were made at both Waltham and Amherst. These studies indicate that training plants to a single stem produces the largest yield. If the plants are trained to two stems, as most growers now train them, the use of potted plants gives a slight increase over plants grown in beds. Of considerable influence on the total yield is the amount of manure used on the land. The use of a fertilizer in which three-fourths of the nitrogen was in organic form was of considerable importance in increasing the yield.

In the production of fruit early in the season, training plants to a single stem and the use of potted plants were the two most important factors. Considering the fact that the price received for fruit from the first four pickings was double that received for the remainder of the crop, the amount of fruit produced early in the season has considerable bearing on the financial success of the tomato crop.

The percentage of the various grades of fruit was not materially influenced by the treatment.

Pascal Celery Storage. (Robert E. Young, Waltham.) The results obtained this year agree with those of the previous experiment, and show that the loss now occurring in growers' storage pits may be lessened and the keeping prolonged by packing the celery about three-fourths as tightly as is now the practice. Aeration, evaporation, and heat loss are greatly increased by the loose pack.

Cutting off the tops of the celery plant and treating the cut tissue with fungicides to prevent rotting was not successful this past year, probably due to lack of proper handling during the re-growing period.

Lowering the humidity in the storage room by the use of cold outside air caused wilting of the top leaves although it did not greatly affect the amount of marketable celery obtained from the compartment.

The results of a comparison of large plants with small ones indicate that the larger the plants are, the larger the marketable stalks are after storage.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

Severe weather during the past year again caused damage to fruit crops. The winter cold was less severe than for the past two years however, and there was a good crop of peaches after two years of crop failure. Spring frosts ruined the crop in a few orchards in the State not favored with good air drainage, but no damage was done to the station orchards. The apple crop was about 25 percent larger than that of 1935.

The Interrelation of Stock and Scion in Apples. (J. K. Shaw.) Applications of muriate of potash to this orchard were made as in the previous two years. This year the potash-fertilized trees were of distinctly better appearance and made better growth than those in the four rows without potash fertilization. It thus appears that lack of potash is one of the reasons for the poor growth and yields of this orchard. Other Experiment Station orchards have shown indications of potash deficiency, but thus far there is no proof that this condition is at all common in Massachusetts. The question is worth investigating. Further study of this orchard cannot be made as it will be removed this winter.

The Influence of Various Clonal Stocks on Apple Varieties. (J. K. Shaw.) The foregoing project has been revised and redirected as a new project to include the work with Malling and other clonal stocks.

Propagation experiments with the Malling and other stocks were continued. Exposure of scions of these stocks to ammonia fumes failed to give clear proof that this was the cause of the poor stands of nurse root grafts obtained last year. Several thousands of nurse root grafts of the Malling stocks were made with better results than in earlier years. They were not dug in the fall but seem to have rooted well.

On account of extremely dry weather in the summer of 1935 the stand of one-year trees budded on the Malling stocks was very poor. The trees budded in 1934 grew into excellent two-year trees and are available for planting in orchards in the State in a cooperative test of the value of the Malling stocks.

A comparison of different ways of treating these trees was made. Some of the one-year whips were cut back in the usual manner at about 32 inches, some were tipped about six inches, and others left with no pruning. All were good one-year trees from three to five feet tall. Measurements taken at digging indicated little difference between the three lots in trunk diameter and the cut-back trees made only little less height growth than the others. Branches on the unpruned trees were well distributed and formed good crotch angles. While no recommendations are made, it may be that cutting back one-year whips in the nursery is an unwise practice.

The South Amherst orchard on Malling Stocks suffered again from dry weather and made little growth. With more rain in early summer these trees may yet start into good growth. The McIntosh–Wealthy orchard at the Station produced heavily. A report on the early years' behavior was made and is listed in this report.

The stool bed of Malling stocks recovered from the severe cutting of 1934 but yielded few rooted plants. It is planned to pin down the shoots next spring and it is expected that a good production of rooted stocks may be obtained in the fall.

Tree Characters of Fruit Varieties. (J. K. Shaw and A. P. French.) Most of the work on this project was done on a 2500-mile trip among the nurseries of Delaware, Maryland, Virginia, Michigan, Ohio, New York, and New England. Twenty nurseries were examined for trueness to name and about 30,000 trees out of some 3,000,000 were found not true to name. Notes were taken on many varieties and our knowledge of tree characters considerably enlarged. Certification work continued on the smaller scale of recent years. This work is done without expense to the public. It is believed that this work during the past fifteen years has resulted in a substantial decrease in the number of misnamed trees reaching the grower, but there is room for further improvement.

Further attempts were made to grow a nursery of cherry varieties for closer study than is possible in a single short visit to commercial nurseries. Success with the buds set last year was again poor. The stocks were rebudded in a final attempt to get a stand of trees. Over forty varieties are included.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) In the spring of 1936 Elberta was selfed to obtain a larger population of selfed Elberta seedlings which are to be used in studying the linkage between flesh toughness and stone adhesion. To study the further inheritance of gland type, Elberta was crossed with a seedling, M-I 18, having eglandular leaves and with a seedling, M-J 15, having wavy leaves with serrate margins and globose glands. The varieties Marigold and Oriole were selfed to see if, by a recombination of characters, seedlings could be obtained which would be more hardy and possess better quality than the parents.

An unsuccessful attempt was made to start the seeds of Marigold and Oriole on an agar medium. Additional pits of Oriole are being held in storage and an attempt will be made to germinate them by the usual method of stratification.

A minimum temperature of –15.5° F. in Block N and –20° F. in Block M on February 20, 1936, killed the fruit buds on a good many of the seedlings but a few seedlings had some fruit.

A selfed seedling of Belle, T-C 18, which was melting and free, when selfed gave the following: 13 tough cling and 46 melting free seedlings.

From T-B 15, a tough cling seedling, selfed, seven seedlings fruited and all were tough cling. From the cross T-B 15 x T-C 19, both tough cling, 11 seedlings fruited and all were tough cling.

Two selfed Early Crawford seedlings, S-K 29 and S-K 31, were crossed to see if size and quality could be improved. In 1936 twenty-eight seedlings from this cross fruited but neither character was improved.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) No change has been made in this project, but it becomes necessary to remove the Baldwin trees leaving only the McIntosh 40 feet apart. The Baldwin trees have continued to give reduced yields on most of the plots, this being attributed to winter injury though no trees have died either wholly or in part. The two plots having a complete fertilizer continued to show improved yields in the case of McIntosh as does the plot receiving nitrogen and potash. Baldwin does not show consistent benefits from potash. Observation of the yields for the past 15 years emphasizes the fact that other factors than fertilizers have potent influence on yields.

Comparison of Clover Sod and Grass in a Sod Mulch Orchard. (J. K. Shaw.) This project, considered closed, has been revived in a different form. With the cooperation of the Forestry Department this orchard of about 55 trees is now being used to observe the value of sawdust as a mulching material. Five rows of five trees each were mulched with sawdust during the past fall and early winter. The remaining trees are in sod which is torn up in the spring to check the growth of the grass. Enough sawdust to check the growth of grass will be used and the soil conditions and growth and behavior of the trees will be studied.

Tests of Different Amounts of Nitrate of Soda. (J. K. Shaw.) In 1922 a block of 20 Baldwin trees then 24 years old growing in sod were assigned for a test of different amounts of nitrate of soda to see the effect on growth and yield and more especially on the color and appearance of the fruit. There were six plots of two or three trees each separated by a guard tree. Each tree received 10 pounds of superphosphate and 3 pounds of sulfate of potash. Nitrate of soda was used on duplicate plots at the rates of 5, 10, and 15 pounds per tree. In 1928 as the larger amounts of nitrate seemed to increase yields with no injurious effects, it was increased to 10, 17½, and 25 pounds per tree. Beginning in 1932 all fertilizer was omitted in the heavier bearing year but applied as usual in the odd years.

While the trees are so few that the results may have little significance, we believe that they are suggestive. A summary of growth and yield follows:

Nitrogen Fertilization	Trunk Diameter		Average total yields per tree, 15 years, bushels
	1921	Increase to 1933	
Light	30.5	15.6	143
Medium	33.0	20.6	166
Heavy	34.5	20.5	206

These figures show increased growth as expected from nitrogen fertilization yet the relative sizes were nearly the same at the beginning as at the end of the test. Apparently yield increases with the increase of nitrogen. Again it should be noted that the yields were in the same order as the size of the trees in 1921. Unfortunately no yield records previous to 1921 are available, yet it was thought at that time that the three groups of trees were nearly alike. One of the heavy nitrogen plots was believed to be inferior to the rest.

The most important question is whether the heavier nitrogen applications injured the trees or fruit. The color and attractiveness of the fruit was in some years somewhat better with the light application but repeated observations indicate that differences were too small to be of importance. None of the fruit was above average, probably because the soil is too shallow and the subsoil too compact to suit the Baldwin.

The trees suffered from the recent cold winters but there is little indication of more injury on the high nitrogen plots. It must be remembered that the orchard has a heavy sod, mostly bluegrass.

The study of these trees suggests that while liberal nitrogen fertilization may have been profitable there are other factors that were influential — probably soil conditions and water supply, also the fact that a complete fertilizer was used. Such heavy applications of nitrogen alone might possibly have given different results. Winter injury has so weakened the trees that for this and other reasons it is expected that the trees will be removed and the test terminated.

Comparison of Cultivation and Heavy Mulching for Apples. (J. K. Shaw.) This project has continued as before. Results are reported in Bulletin 328 issued during the year. The practice of mulching with hay or similar materials brought into the orchard is increasing in Massachusetts. In view of the good results obtained and especially its value in preventing soil erosion and favoring a more uniform and adequate water supply, the practice is to be recommended where the cost is not too great.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw.) This has been continued with own-rooted trees planted in 1931, the fertilizer applications being the same. No radical change has been made in the fertilizer used since 1889 except one change from gypsum to a complete fertilizer. On account of limited space these trees can remain for only a very few years more.

There was a scattered crop in 1936.

Role of Lime and Potash in Fruit Tree Nutrition. (J. K. Shaw.) No work has been carried on during the past two years. A considerable amount of data await study and possible publication.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw.) This has continued as in past years. The practice of cutting up the sod in the spring seems to have been a good one, but some of the trees especially those on the plots without nitrogen have suffered from the recent cold winters. The trees fertilized with potash and phosphoric acid in addition to nitrogen continue to produce the best while those without nitrogen show inferior yields.

Study of Varieties of Fruits. (J. K. Shaw and staff.) Observations were continued on several hundred varieties of different deciduous fruits. Most of these are new or little known; among them may be a few that will prove of value to Massachusetts fruit growers. We are trying to single out these few.

Apples. The so-called red bud sports continue to excite interest and some are gaining in popularity. In the group of Delicious-like apples, Richared seems to stand out as the most attractive in appearance and to be equal in other ways to Delicious, Starking, Medina, and Orleans. The Red Gravenstein is reported to be favored in the market and seems equal in every way to Gravenstein; it seems to keep longer which may or may not be desirable. Golden Delicious continues to be promising as a winter apple for dessert use. As with all new varieties, the grower must learn how to grow it. It is inclined to russet in our humid climate and so is less attractive than when grown in dryer climates of the west.

Kendall has not fruited with us yet but we have seen fruit grown elsewhere and its resemblance to McIntosh is striking. The dots of the skin are more conspicuous, the flesh greener and it will doubtless keep longer. In quality it may not be quite equal to McIntosh but is very good. The tree characters are very good. It seems to be more promising as a commercial variety than Macoun.

Among the several early red varieties from the United States Department of Agriculture mentioned in our report for 1933 Nos. 34 and 312 seem most promising; the first being a little earlier than Yellow Transparent and the second possibly a little later. Both are of good size, attractive, and of good quality. They ripened from July 23 to August 7 in 1936. No. 57 ripens with 34 and is promising but present knowledge indicates it to be a little inferior for our conditions. None of these varieties are available in the market but are under test in several places and have been propagated in our nurseries.

Pears. Gorham continues to be promising and we have several other varieties propagated at the New York Station some of which may prove of value but require further study.

Plums. Mention has been made of Wrights Early in past reports. The one tree we have suffered from winter cold and the plums borne this year were small. But it is hardier than Beauty and Red June, competing varieties of the same season.

Peaches. While the peach variety orchard produced a crop after two years of complete failure, many of the trees have been injured or killed. Golden Jubilee is becoming a standard variety and Halehaven promises to replace South Haven and other varieties of its season. Oriole is very productive and gains in favor. Pioneer is a good white peach.

Raspberry. We have 26 numbered seedlings from the New York Experiment

Station under observation, 2 or 3 of which have been named. All are good but naturally very few will prove worthy of cultivation. Newburgh, Taylor, Marcy, and Latham ripened in the order given. The mosaic disease in Newburgh observed for the first time last year did not make serious progress. The new everbearing variety, Indian Summer, did not mature its fall crop but the early crop was fully equal to that of St. Regis (Ranere).

Strawberry. Further observation of Dorset and Fairfax indicate that they are not heavy producers with us and that spacing of the plants is desirable as has been recommended.

Howard Supreme continued to be our heaviest producing variety but for some reason it does not seem to meet with favor with others, perhaps because it is an imperfect variety and does not yield as well under other conditions.

Catskill fruited for the first time and is promising. Aberdeen still seems about the best late variety.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter.) To study the effects of time of planting on fruit bud formation, plots of 51 plants each were set on April 29, May 15, and June 1, 1935. Each planting was replicated five times. To eliminate complications arising from a varying stand of plants, each parent plant was allowed to form two runner plants only.

These plots were harvested in 1936. There were no significant differences in number of fruits per plant.

To study the effects on fruiting of CO_2 in the soil, one-third of the plants in each plot were fertilized with two ounces of dextrose per plant on July 18, one-third were fertilized with one ounce of dextrose and one-half ounce of nitrate of soda, and one-third were left untreated. Both treatments reduced yields slightly, on both mother and runner plants.

Bud Mutations. (J. K. Shaw and W. H. Thies.) These top-worked trees of several strains of Wealthy, Gravenstein, Baldwin, and Stayman bore a scattered crop but not enough to permit many comparisons. In some cases, the supposed bud sport varied little, if at all, from the usual type of the variety but there were two red strains of Gravenstein. Further observations are necessary before attempting to evaluate these strains.

Storage of Apples Under Various Conditions. (O. C. Roberts cooperating with Agricultural Engineering Department.) This project consists of a study of the keeping quality of McIntosh apples under varying conditions of temperature and humidity. The results obtained indicate that McIntosh apples that are held for a short period at 40°–45° F. after harvest before being cooled to 32° develop a better flavor than apples held at 32° F. continuously, and also that apples held under "modified" storage will hold in marketable condition until January first or later.

Tests of Various Spray Materials. (O. C. Roberts, cooperating with Entomology and Botany Departments.) Observations were made on the effects of various fungicides on scab control. Detailed report of this project will be found under report of Entomology Department.

The relative merits of zinc arsenate and lead arsenate in the control of insect pests were studied in cooperation with Entomology Department. Details may be found in the report of that Department.

Elimination of Arsenic and Lead Residues from Apples. (O. C. Roberts and J. K. Shaw cooperating with Departments of Entomology, Agricultural Engineering, and the Fertilizer Control Service.) In this experiment

McIntosh and Baldwin trees were grouped so that one group received no lead arsenate spray after the calyx, another group received no lead arsenate spray after the first cover, and so on through all of the cover sprays. Representative samples were selected from trees in each group and analyzed for lead and arsenic residue. The following table shows the results of the analysis on McIntosh. The analysis on Baldwin has not been completed.

Date of Last Application of Lead Arsenate	Grains per pound of fruit	
	Lead (Pb)	Arsenic trioxide (AS_2O_3)
Calyx — May 20	.003	00105
1st cover — May 28	.003	.0021
2nd cover — June 5	.0075	.0051
3rd cover — July 14	.015	.0077
4th cover — July 30	.024	.0165

These results are in accord with those obtained in previous tests and indicate that when lead arsenate in the form of spray is applied as recommended in the official spray schedule within eight weeks of harvest there is a possibility of the lead and arsenic residue exceeding the tolerance of .018 gr. per lb. for lead and .01 gr. per lb. for arsenic trioxide established by the United States Food and Drug Administration. Previous experiments have shown conclusively that if dust is used instead of a spray for the 3rd and 4th cover applications, the residue from both lead and arsenic is confined well within the limits of tolerance.

The Nutrition of the Highbush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) In October 1936 the work on the nutrition of blueberries was organized as a Bankhead-Jones project.

The experiment to try out the acidification of the soil under field conditions started in 1935 was continued during 1936. In the Brooks nursery the plants growing in the soils treated in 1935 with sulfur, with aluminum sulfate, and with aluminum chloride all made better growth than those in the untreated soil. Also the leaves of the plants in the treated soils were much darker green in color. The plants in the soil treated with aluminum sulfate appeared the best. This difference was distinctly noticeable by the middle of July.

A similar experiment was started in a nursery set on the Harlow farm in 1936. One plot was left untreated, another received aluminum sulfate at the rate of 400 pounds per acre, and another aluminum sulfate at the rate of 800 pounds per acre. These treatments were replicated three times. The pH changes in the plots were as follows:

Treatment	Plot No.	pH		Plot No.	pH		Plot No.	pH	
		5/18/36	9/1/36		5/18/36	9/1/36		5/18/36	9/1/36
Untreated	1	5.55	5.25	4	5.60	5.50	7	5.55	5.30
400 $Al_2(SO_4)_3$	2	5.65	5.30	5	5.70	5.50	8	5.25	5.20
800 $Al_2(SO_4)_3$	3	5.60	5.40	6	5.60	5.30	9	5.20	4.70

The pH of all plots decreased during the season. The plants have shown no differences in response to the differential treatments.

In the spring of 1936 an experiment was started to test out several materials as soil acidifiers for blueberries. The materials used were sulfur, aluminum chloride, aluminum sulfate, citric acid, hydrochloric acid, and phosphoric acid. Lime and untreated soil were used for comparison. The chemicals were each used at four different rates of application. Three-gallon glazed earthenware crocks were used to hold soil and plants. Ten kilograms of treated soil were placed in each crock; 5 crocks were used per treatment. Plants were of the variety Rubel. Treatments were as follows: sulfur 1, 2, 4, 8 gms. per crock; aluminum chloride, 5, 10, 20, 40 gms.; aluminum sulfate, 7, 14, 28, 55 gms.; citric acid 62, 125, 250, 500 cc. of molecular solution per crock; hydrochloric acid 62, 125, 250, 500 cc. of normal solution; orthophosphoric acid (H_3PO_4) 62, 125, 250, 500 cc. of normal solution; and lime 5, 10, 20, 40 gms. per crock. The following statements are based on this year's results with the soil used.

1. H_3PO_4 gave the best growth of plants of any of the chemicals tried.

2. Aluminum sulfate and sulfur were about equally effective in producing soil acidity and produced about equal growth response, but previous experiments show that too much sulfur may injure the plants.

3. Aluminum chloride did not increase acidity as much as aluminum sulfate and reduced the growth of the plants.

4. Citric acid reduced rather than increased acidity and reduced the growth of plants.

5. HCl in all concentrations was toxic to the plants.

6. Lime in all amounts used appeared to reduce the growth of plants.

During 1936 the work on the chlorosis of blueberry plants was continued. Several different chemicals, some as sprays and some as soil amendments, were applied to affected bushes. Ammonium sulfate was the only one of these to which the plants showed a definite favorable response. A preliminary report of this work will appear in the *Annual Report* of the *American Society for Horticultural Science for 1936.*

Blueberry Culture. (J. S. Bailey.) In the spring of 1936 an experiment was started in cooperation with Dr. Frank Shaw of the Department of Entomology to test the effectiveness of honey bees as pollinators for highbush blueberries and also to observe the insects which visit blueberry bushes exposed to open pollination. A cage 5′ x 10′ x 10′ was placed over one bush each of the varieties Harding and Pioneer and another over the varieties Pioneer and Grover. A branch of each bush was covered with cheesecloth to exclude bees. A nucleus hive of honey bees was placed in each cage. Counts of the berries set gave the following:

	Number of fruits set	
Variety	With bees	Without bees
Harding	42	0
Pioneer	16	0
Grover	36	0
Pioneer	32	3

The set of fruit on the caged bushes was as good as that on bushes exposed to open pollination.

Collections of all insects visiting blueberry bushes were made at different hours of the day from May 21 to May 26. The following table lists those insects which have been identified:

Bumble bees		Solitary bees		Honey Bees
Bombus impatiens	23	Colletes	22	56
Bombus perplexus	45	Halictus	20	—
		Andrena	30	
Total	68		72	56

The pollination experiments with blueberries were continued in 1936. The work was done under tents of aster cloth and pollination was by hand. Results for 1936 were as follows:

Selfing

Variety	Percent Set	Variety	Percent Set
Dunfee	1.5	Wareham	2.5
Sam	2.3	Concord	71.2
Harding	0.8	Rancocas	29.0
Adams	22.7	Scammell	39.5
Katherine	4.5	Jersey	60.9
Pioneer	2.2	Cabot	40 2
Stanley	21.0	Grover	0.5
FI-66	26.0	Rubel	40.8

Crosses

Variety	Percent Set
Rubel x Pioneer	11.8
Rubel x Cabot	16.0
Pioneer x Rubel	6.8
Pioneer x Cabot	9.2
Cabot x Pioneer	63.5
Cabot x Rubel	29.0

Premature Dropping of the McIntosh Apple. (Lawrence Southwick.) Work on this project was started in late August 1936, when six individual trees located in two blocks were chosen for detailed study. In Block E two trees in each of two plots were selected as representing extremes in dropping percentages. The average percentage of drop during the period 1928–1935 was taken as a basis of comparison and this varied from 11 to 34 percent. From 300 to 400 apples on each tree were numbered with India ink and calipered. In each case, detailed spur and leaf data were taken. From September 8 to October 14 the "drops" were gathered at least once a day and placed in cold storage for later study. In Block P, 1,000 apples, representing the greater part of the crop of one tree, were numbered as above and tags bearing identical numbers in each case were attached to the respective spurs. Spur and leaf data were taken as before and the drops handled in the same way.

The data are now being classified for detailed correlation studies in an attempt to ascertain just what individual causal factors initiate the abscission process. No conclusions have been reached at the time of this writing.

DEPARTMENT OF POULTRY HUSBANDRY

J. C. Graham in Charge

Broodiness in Poultry. (F. A. Hays.) Attempts are still being made to establish a genetically non-broody strain of Rhode Island Reds. The generation of birds hatched in 1935 and now having a complete first-year record was produced by two untested males mated for the most part to aged females that had not exhibited broodiness during their first laying year and some of these females had three complete years without broodiness. Out of five families of daughters sired by one male there were two families showing broodiness. From this male there was a total of 34 daughters, two of which became broody. The second male also produced five families of daughters, four of which exhibited broodiness. The total number of daughters was 30, and 5 of this number became broody in the first laying year. In the entire flock bred for egg production only 4.73 percent of the birds were broody during the first laying year. The mode of attack appears to lie in the use of aged males and females that have been shown by breeding tests to lack the dominant genes for broodiness.

Breeding Poultry for Egg Production. (F. A. Hays and Ruby Sanborn.) A number of phases of the problem of breeding for high fecundity have been studied during the past year. The flock has been constantly selected for high hatchability. The hatching records for 1936 show significant progress. From eight pedigree hatches at weekly intervals during March and April, a total of 6,604 eggs set gave a mean hatchability of fertile eggs of 84.31 percent.

Body weight has increased in the flock, the mean weight at first egg being 6.2 pounds for a mean age of 194 days. Egg size has been significantly increased to a mean of 56.3 grams from first egg to January first. Broodiness stood at a new low figure of 4.73 percent. Mean annual egg production for the flock just finished was 220.4 eggs. This mean is based on all birds that survive, without culling. Mortality rate of pullets in the laying houses was greatly reduced to the low level of 13.2 percent for the first laying year. The production-bred flock has also been improved in chick feathering.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn.) Data have been prepared and published as follows: Studies on the Inheritance of Persistency, Genetics 21:519–524, 1936; Winter Pause in Rhode Island Reds, Station Bul. 329, 1936; Time Interval Between Eggs of Rhode Island Red Pullets, Jour. Agr. Res. 52:633–638; Numbers and Uniformity in Experimental Lots, Poult. Sci. 15:235–238, 1936; Inheritance of Sexual Maturity in Rhode Island Reds, Proc. Sixth World's Poult. Cong. pp. 34–38, 1936; Hatchability as Related to Season and Hour of Laying (in press).

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) Two lines of exhibition stock have been maintained. One line has been bred for plumage color alone and the behavior of egg production character has been studied. The other line has been bred for characters affecting egg production without sacrificing desirable plumage color. Neither line has reached a high production level but some promising families and individuals have appeared. The difficulty in making progress in small units constantly appears.

Rate of Feathering in Rhode Island Reds. (F. A. Hays.) Early-feathered and late-feathered lines are being developed on the basis of back feathering at eight to nine weeks of age. After three generations of breeding the first line shows about 50 percent early feathered and the second line about 10 percent early feathered. The data point to two rather definite facts. First, that early-feathered females cannot be distinguished from late-feathered females at eight weeks of age. Second, that early feathering is recessive and depends not only upon a sex-linked gene but also on two or more autosomal genes.

Breeding for Low Mortality. (F. A. Hays.) Two generations of lines bred for high and low mortality in the laying houses have complete records. Each line has been selected entirely on mortality rate without regard to egg production characters. Laying-house mortality in the first generation was 55 percent and 44 percent respectively for the two lines. The corresponding first-year egg production for the survivors was 192 and 230. The second generation hatched in 1935 gave a laying-house mortality of 19 percent and 0 percent respectively for the high and low mortality lines. The mean annual egg records of the two lines were 209 and 257.

Breeding for High and Low Resistance to Fowl Paralysis. (F. A. Hays, W. C. Sanctuary and J. H. Vondell.) The studies to date indicate that different degrees of resistance to fowl paralysis exist. Since the mode of transmission is little understood, progress has been slow. Recurrent waves of the disease are difficult to explain in stocks of birds bred under uniform conditions from year to year. Specific phases of this disease are now being investigated.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint, and M. K. Clarke.)

1. *Pullorum Disease Eradication.* During the 1935–36 testing season a total of 255 flocks (including three flocks of poultry other than chickens) representing 344,233 samples (including 152 from fowl other than chickens) was tested. The testing results of the chicken flocks showed increases in tested flocks (8), tested birds (48,535), tests (42,194), and non-reacting flocks (17) over the previous season. The average percentage of positive tests was 0.30, which is the lowest attained during the sixteen-year testing period. Of the total birds tested, 95.6 percent were in 230 non-reacting flocks, a definite increase over the percentage (89.5) for the 1934–35 season. Furthermore, among the 315,215 birds in the negative flocks, 90.9 percent were in the 100 percent tested flocks.

The merit of annual testing is emphasized by the following data presented on 151 flocks which were tested for three or more consecutive years. Among 271,410 blood samples collected from 263,400 birds only 0.10 percent gave a positive test. The number of birds in flocks tested for three or more consecutive years represented 79.9 percent of the total birds tested.

The results for the 1935–36 testing season show steady progress in pullorum disease eradication. The data prove that poultrymen who follow a conscientious testing and disease-prevention program are able to maintain a pullorum clean flock.

2. *Pullorum Disease Investigations.*

(a) Antigenicity Studies of *S. pullorum* Strains. The purpose of this investigation was to determine whether or not the agglutinative sensitivity of certain selected strains of *Salmonella pullorum* could be increased by serial passage through day-old chicks. Duplicate sets of three strains employed in the antigen for routine pullorum disease testing were selected. Day-old chicks were inoculated subcutaneously with viable fresh antigen and held for a short observation period. Each lot of chicks was inoculated with antigens prepared from cultures recovered from the preceding lot of chicks. The organisms were properly identified after each isolation. Antigens were prepared from the isolated strains and tested with known positive and negative sera. A standard stock antigen composed of the three strains was tested simultaneously with the same sera. Following the serial passage of the six strains of *S. pullorum* through twelve lots of chicks, no change was noted in the agglutinative sensitivity of the strains.

(b) Viability of *S. pullorum*. Viability studies, which are still in progress, have shown that *S. pullorum* has remained alive in a dry piece of cloth for a period of four and one-half years.

(c) Whole-Blood Agglutination Test. During the past year investigations concerning the whole-blood test have been continued in order to improve its efficiency. A change in the technique consisting of more accurate measurements of whole blood and antigen was tried. Limited data suggest that the efficiency of the whole-blood test is increased when a serological pipette is used to measure definite, constant quantities of whole blood and antigen.

(d) Maltose-Fermenting *S. pullorum* Strains. During the past six years *S. pullorum* strains which were retained as stock cultures have been observed to acquire the property to attack maltose. The behavior of these and other strains toward maltose has been studied. It was found that strains which possessed a potential tendency to ferment maltose could be identified by cultivating them in a maltose-peptone solution for a period of time. Some strains acquired this property much sooner than others. Strains undergoing a change in behavior toward maltose would exhibit red and white colonies when plated on a modified Endo's medium (maltose substituted for lactose). Among twelve maltose-fermenting strains studied, only one failed to show white colonies on this medium, suggesting that complete conversion had occurred. Strains that produced both maltose-fermenting and non-maltose-fermenting colonies exhibited only non-maltose-fermenting colonies after being subjected to animal passage. An apparent pure maltose-fermenting strain did not lose this property when subjected to animal passage.

(e) Pullorum Disease in Turkeys. Pullorum disease was encountered in two turkey flocks during the past year.

Flock 1. Two consignments of poults were received from this flock. The clinical history which was reported for the first consignment and the lesions observed were suggestive of pullorum disease. A 25 percent mortality was experienced during the first nine days after hatching. A second consignment, received approximately a month later, represented poults that were hatched on a later date. The poults were approximately five weeks of age and greatly stunted. The sera of five poults were tested with pullorum antigen in three dilutions (1:25, 1:50, 1:100). Three sera produced no agglutination, but two completely agglutinated the antigen in all three dilutions. *S. pullorum* was isolated from one of the five poults and the serum of this bird was also positive. Incomplete evidence suggests that the infection might have originated in a custom hatchery. When the survivors of the outbreak were approximately six months old their sera were tested with pullorum antigen. Among 118 birds tested 28.81 percent exhibited reactions which varied in degree with a maximum titre of 1:320. Through the cooperation of the flock owner it was made possible to examine bacteriologically some of the reacting birds which had been dressed for the holiday trade. Cultures were taken from eight birds and *S. pullorum* was isolated from three. The agglutination titres of the three birds were 1:20, 1:40, and 1:320. A program is in progress to eradicate pullorum infection from this flock through short-interval testing.

Flock 2. Pullorum disease was diagnosed in two-weeks-old poults which suffered approximately a 33 percent mortality. The history of the consignment revealed that losses were confined to a group of 200 poults which had been received from a mid-western state. The balance (1,800) of the flock did not appear to be infected.

3. *Disease Studies in Wild Animals.* During the past year the collection of normal and diseased specimens of wildlife has increased. Specimens of ruffed

grouse and Chinese ring-neck pheasants, which were being reared in captivity by the Poultry Department, revealed that the cause of the mortality among the former was apparently of a managerial nature. The majority of the losses in ruffed grouse occurred within the first two weeks of age.

Paratyphoid infection was encountered in a young pheasant flock on one of the State game farms. Approximately two months after the outbreak, the sera of the survivals were tested with an antigen prepared from the paratyphoid organism and no reactors were detected. To date, no further signs of this disease have been observed in the flock.

4. *Diagnostic Service.* The number of cases diagnosed was 497, personal delivery of specimens being made 279 times. The classification of 2,087 specimens follows: — 1,721 chickens, 143 turkeys, 49 pheasants, 26 ruffed grouse, 15 swine, 4 fecal samples, 4 muskrats, 4 rabbits, 3 foxes, 2 each of feed, pigeons, skunks, and one each of beet pulp, budgerigar, bovine, canine, cow's liver, deer, goat, goose, horse blood, raccoon, rat, and tissue. The diseases encountered most frequently were coccidiosis, pullorum disease, neoplasms, "avian paralysis," parasitism, "epidemic tremor," and kidney disorders. So-called "crazy chicks," which had not been observed in the previous two years, were noted in 10 cases. Avian tuberculosis and fowl typhoid were not observed. Fowl cholera was detected on two premises on one of which it had been diagnosed the previous year. Paratyphoid infection in chickens was encountered once in pigeons and twice in turkeys. Two cases of pullorum disease in turkeys were noted.

Two diseases among turkeys not previously observed by this laboratory were encountered during the past year. The one was "ulcerative enteritis," which appeared similar to that observed in grouse and quail. This diagnosis was confirmed through the courtesy of Doctor J. E. Shillinger and his co-workers, Bureau of Biological Survey, United States Department of Agriculture, Washington, D. C. The other disease was caused by an organism which resembles *Erysipelothrix rhusiopathiae,* causative agent of swine erysipelas.

5. *Flock Mortality Studies.* During the past year, mortality studies were continued in one flock and started in another. Flock A — from 765 pullets placed in the laying houses in September 1935, 47 birds were submitted for necropsy during the laying year. These 47 birds represented 40 percent of the total mortality. The disturbances diagnosed most frequently were reproductive disorders 15, nephritis and visceral gout 8, neoplasms 5, and leukemia 4. Flock B — since this flock has not completed its laying year, the results are incomplete and will be reported at a future time.

6. *"Epidemic Tremor" in Chicks.* During the past year chicks were received from 29 affected flocks in some of which mortalities were reported to be greater than in outbreaks observed previously. In some cases, maximum losses amounted to 50 percent of the chick flock.

From 14 pullets which were survivals of naturally infected chicks received in the spring of 1935, a total of 239 chicks were hatched. The majority of chicks were held for observation up to six weeks of age or longer. None of the chicks exhibited the symptom complex observed in "epidemic tremor," although a few of the birds, as they became more mature, developed an eye condition which has also been observed in naturally infected birds. The gross pathological changes consisted of an apparent enlargement of the eyeball, degenerative changes in the lens (marked degree of opacity), and a seemingly fixed pupil. Some birds appeared to be totally blind. Hatching experiments are being repeated with a group of pullets obtained as chicks in 1936.

Attempts to transmit the disease artificially have been successful. The various aspects of the disease are now being investigated, and the results will be reported in greater detail elsewhere.

7. *Farm Department Bang Disease.* The laboratory cooperated by testing, with the standard tube agglutination method, 758 blood samples from cattle and 101 blood samples from pigs. Upon the basis of several years' testing work and a required final qualifying test by the official laboratory, the college herd received a Bang Abortion Disease-Free Accredited Herd certificate from the Massachusetts Division of Live Stock Disease Control in November, 1936.

Observations and Experiments with Neurolymphomatosis and the Leukotic Diseases. (C. S. Gibbs.) A report is in the process of publication as Bulletin 337.

WALTHAM FIELD STATION

(Waltham, Massachusetts)

Ray M. Koon, in Charge

For reports on approved projects conducted at this station, in addition to those listed under this caption, see reports of the Departments of Botany, Entomology, Floriculture, Horticulture, and Olericulture.

Consultation and Information Service. Along with its function as a research unit of the College, the Field Station has continued to expand its service as an information center. Commercial growers and amateur gardeners are finding this service of increasing value as evidenced by more than 3,600 telephone calls and 3,800 visitors seeking help during 1936. In addition, 807 came to attend meetings of thirty garden clubs which were held at the Field Station. The Boston Market Gardeners Association, the Boston Branch of the National Gardeners Association, the National Shade Tree Conference, and the Massachusetts Association of Greenkeepers, held well-attended meetings here in which members of the Field Station staff participated.

Paul W. Dempsey was appointed to relieve the research men of the burden of some of this growing activity but has only been able to take care of the increase. At the request of various organizations he has given 124 talks on the work of the Field Station and on general horticultural subjects during the year.

The ornamental display and test gardens attracted 3,500 visitors from June 1 to September 1. Increasing numbers of both commercial and amateur gardeners are visiting these gardens several times during the season to observe the behavior of new introductions as compared with some of the older standard varieties.

Field Day. The Eighteenth Annual Field Day was held on August 5 with an attendance of 1,200. The number of vegetable contests held at this time is gradually being increased with the hope of making them an important part of the Field Day program. The following contests were held this year: Celery, Bunched Carrot, Pepper, Trellis Tomato, and Bunched Beet. Next year Summer Squash will be added. The quality of the vegetables exhibited at these contests is second to none.

Soil Testing Service. (Robert E. Young, Harold E. White, and Paul W. Dempsey.) The total number of samples of soil submitted for testing was almost double that of last year. With the better understanding of the importance of the minor elements, an increasing number of commercial growers are requesting that in addition to the regular tests for acidity, nitrogen, and phosphorus, further determinations be made for potassium, calcium, magnesium, aluminum, manganese, and other elements.

Summary of Soil Tests

Greenhouse:	
Flower	462
Vegetable	239
Market Gardeners	450
Miscellaneous*	1,553
Total soils	2,704
Total determinations	8,975

*Includes amateur gardeners, golf courses, landscape gardeners, Metropolitan District Commission, and W.P.A. engineers.

Vegetable Variety Trials. (Paul W. Dempsey.) The sweet corn variety test again included a number of the new hybrid varieties together with most of the old and new standard varieties. On account of the absence of Stewart's Disease, it was impossible to obtain resistance records. The hybrid varieties are being adopted rather slowly by corn growers in this State. With the introduction of earlier maturing hybrid varieties, our growers will undoubtedly become more interested.

Outdoor tomatoes have always been an important crop in our market gardens. During the past five years the method of growing the greater proportion of this crop has changed from flat culture to trellis culture. No change in the cultural methods of growing a vegetable crop in this State has taken place so quickly or with so much satisfaction to grower, seller, and consumer. Because of this change, we are concentrating our variety trials on strains which may be of value for growing by the trellis method. Our own development, the Field Station Comet (Waltham Forcing Tomato) has been outstanding in these trials for several years (see Department of Olericulture, Vegetable Breeding for Improvement of Quality.)

The Plant House. (Paul W. Dempsey.) Interest in the two plant houses at the Field Station and in the plans available for distribution has been maintained at about the same level during the past few years. Fuel costs for operating the houses during the past three severe winters have remained close to the original estimate of $75.00 for each house.

Electricity as a Source of Heat in the Hotbed and Propagating Bench. (Paul W. Dempsey.) Very little interest in electrical heat has been evidenced by either commercial or amateur growers. Current costs are high throughout this State.

Interest in an electrical soil sterilizer is increasing as growers of annual and perennial plants have suffered considerable loss from soil organisms. The rural development representative of the local power company has recently designed a simple sterilizer, one of which he has placed at the Field Station for trial.

PUBLICATIONS

Bulletins

317 Blueberry Culture in Massachusetts. John S. Bailey and Henry J. Franklin. 20 pp. illus. February 1935, Revised May 1936.

327 Annual Report for the Fiscal Year Ending November 30, 1935. 84 pp. February 1936.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

328 Heavy Mulching in Bearing Apple Orchards. J. K. Shaw and L. Southwick. 15 pp. illus. March 1936.

McIntosh and Wealthy apple trees were observed during a fifteen-year period under a comparison of heavy mulch and cultivation with a cover crop. No additional fertilizer was used on the mulched plots; the cultivated plots received nitrate of soda at the rate of 300 pounds per acre during the last six years only.

The moisture content of the surface layer of soil differed little except during dry periods when it was higher under the mulch. Soil temperature during the growing season differed little except during warm periods when it was a little lower under the mulch. After the first three years the soil nitrates were much higher under the mulch, but did not produce excessive growth of trees.

Growth and yield of trees was greater under the mulch system than under cultivation. Fruit on the mulched trees matured a little later, but no marked differences in color or quality were observed.

This work suggests that heavy mulching is a satisfactory system of orchard management. The chief objection is cost.

329 Winter Pause in Rhode Island Reds. F. A. Hays. 11 pp. illus. March 1936.

The birds studied were hatched between March 4 and April 23, and those hatched in March showed a somewhat higher incidence of pause than the ones hatched in April. There seemed to be no relation between winter pause and age at first egg, weight at first egg, mean body weight to March 1, laying-house mortality, or hatchability. Short intervals between eggs of a clutch during the winter months, large winter clutch size, the ability to lay large numbers of eggs over a long period before pausing — all had a tendency to shorten the winter pause. There was no evidence for looking upon winter pause as a recuperative period to be followed by increased egg production.

Winter pause caused birds to lose an average of about 37 days in the winter production period and very significantly reduced winter egg production.

330 The Bulbous Iris and Its Outdoor Culture in Massachusetts. Frank A. Waugh. 15 pp. illus. April 1936.

Although bulbous irises are among the most beautiful and adaptable groups of flowering plants, the belief that they are not hardy for this latitude has hindered their general introduction. However, in growing these irises out of doors over a period of thirty years, we have never had a single convincing case of loss from winter freezing, and they are apparently quite as winter-hardy as Darwin tulips or tiger lilies. A large number of varieties are listed with notes on color, size, date of bloom, and general desirability. Methods of culture are outlined, and recommendations made of the varieties most suitable for beginners.

331 The Development of the Testes and Scrotum of the Ram, Bull, and Boar. Ralph W. Phillips and Frederick N. Andrews. 16 pp. illus. April 1936.

A knowledge of the normal course of development of the testes and scrotum is necessary as a basis for the management and feeding of young developing males.

In the studies here reported development of the germinal epithelium of the testes was first noted at the age of 84 days in the ram and boar, and 142 days in the bull, and spermatozoa first appeared at the age of 147 days in the ram and boar and 224 days in the bull.

The tunica dartos muscle first showed marked reaction to temperature changes at 63 to 84 days in the ram and 105 days in the boar, while results with the bull were variable. With boars, a low plane of nutrition resulted in a considerable retardation of the development of the testes and also of the tunica dartos muscle.

The evidence presented seems to indicate that the tunica dartos muscle is dependent upon a testicular hormone for the development and maintenance of its sensitivity to temperature changes.

332 The Cranberry Industry in Massachusetts. C. D. Stevens, H. J. Franklin, C. I. Gunness, and V. C. Peterson. 36 pp. illus. June 1936.

As cranberries are a perishable product with a rather brief marketing season, it is important that those who grow and market them should have reliable estimates of the size of the crop if it is to be sold to the best advantage. Such estimates are essential to the development of sound advertising and price policies. To provide an adequate basis for estimating the crop, special surveys of acreage, management, and production, and of disposal of the fruit must be made from time to time, for it has been found that census data and assessors' reports do not furnish adequate information. The present survey, made in 1934, is compared with the last previous survey (1924), important changes in the industry being noted. The statistical material is presented rather fully in tabular form, and is freely illustrated with charts.

333 A Study in Soil Nitrogen. F. W. Morse. 20 pp. July 1936.

For twelve years, continuous production of nonleguminous crops has been compared with the alternation of a legume with a nonlegume crop, and continuous absence of nitrogen fertilizers, with the alternation of applied nitrogen with residual nitrogen. Analyses of the soils showed no evidence of accumulation of nitrogen resulting from the application of nitrogen fertilizers or from the growth of legume crops; nor any depletion of soil nitrogen resulting from continuous production of nonleguminous crops. On plots which had received no nitrogen fertilizers for forty years, and where no legumes had been grown, the soil appeared capable of supplying to nonlegume crops growing during the summer months an average of 40 pounds per acre of nitrogen, with no measurable depletion. Grasses and spring grains seemed unable to secure as large an amount of nitrogen from the soil without nitrogen fertilizers.

Results obtained with the legume crops are in accord with the accepted facts about the synthesis of nitrogen from the air by symbiotic bacteria in the soil. Results with the nonlegume crops are strongly indicative of the presence in the soil of nonsymbiotic microorganisms which are adding to the supply of nitrogen that is available for such crops.

334 Dried Blood as a Source of Protein for Dairy Cows. J. G. Archibald. 7 pp. October 1936.

Dried blood has been compared, as regards its suitability for dairy cows, with a mixture of soybean meal and cottonseed meal. From the standpoint of palatability and the absence of any unfavorable effects on the animals, it seems evident that dried blood can be safely used as a component of grain mixtures fed to dairy cows to the extent of at least 10 percent of the mixture. In view of our general knowledge of the protein requirements of milking cows and the fact that there was not a significant difference in milk production on the two rations it seems reasonable to conclude that the blood was a satisfactory source of protein as a substitute for a mixture of soybean meal and cottonseed meal.

335 Some FactorsAffecting the Properties of Whipping Cream and the Quality of the Finished Product. W. S. Mueller, M. J. Mack, and H. G. Lindquist. 24 pp. illus. November 1936.

A mechanical whipper of constant speed was used in all these studies, and other conditions were carefully controlled so that accurate comparisons are possible. Some of the factors studied were found to have little or no effect on whipping ability and quality of the whipped cream — time and method of standardization using either whole or skim milk; aging for more than 24 hours; variation in pasteurization temperature from 145 to 165° F.; homogenization; delayed cooling after pasteurization; increase in serum solids to 11 percent by the use of skim milk powder or plain condensed skim milk; the source of protein in the feed of the animals (vegetable or animal). Several substances designed to reduce serum drainage were added to cream before pasteurization. Since they were of somewhat doubtful value, and since the addition of any substance to whipping cream is illegal in many places, their use cannot be recommended.

A whipping temperature of 40° produced a better whipped cream than any higher temperature; and a separation temperature of 90° proved better than 100°. Time of adding sugar was important; but the addition of 5, 10, or 15 percent of sugar after 1 minute of whipping had no detrimental effect. Reconstituted cream (butter and skim milk homogenized) was less desirable in whipping ability and flavor than fresh cream.

Cream completely frozen while in the hands of the producer (before processing) loses most of its whipping properties; but cream totally frozen after processing (for instance while standing on the customer's doorstep) is only slightly damaged.

336 Apple Cider and Cider Products. J. A. Clague and C. R. Fellers. 36 pp. illus. November 1936.

To present results from experiments on several varieties of Massachusetts apples as well as work done by investigators in other states and countries, is the object of this bulletin. The chemical composition of ciders from different varieties of apples is given, with a comparison of factors determining quality, and suggestions for blending two or more varieties to obtain a more desirable product. The bulletin describes methods of pressing, clarifying, filtering, preserving, carbonating, and making concentrated cider products. Uses for apple pomace are suggested, and legal aspects of the alcoholic content of ciders discussed, as well as the problem of spray residues and the nutritive value of cider. A list of firms selling various kinds of equipment and supplies used in cider making is appended.

337 Observations and Experiments with Neurolymphomatosis and the Leukotic Diseases. C. S. Gibbs. 31 pp. illus.

Erythroleukosis and myeloleukosis are filtrable virus diseases which are more apt to occur in chickens less than a year old than in older birds. Predisposing factors appear to be mites, warm weather, and overcrowding.

Lympholeukosis is due to a histogenous cell found in the liver, spleen, and portal blood of affected birds. It was transmitted from diseased to healthy chickens by inoculating portal blood directly into the blood stream or the abdominal cavity. There was no evidence that a virus is involved.

Neurolymphomatosis (so-called avian paralysis) is also due to a histogenous cell, similar to that involved in lympholeukosis except that it has a special predilection for the nervous system. Evidence is presented that the disease is transmitted to the chicken through the egg by the hen and possibly by the rooster. In this study the disease was not so transmitted unless the reproductive organs were infiltrated with neurolymphomatous cells. In the case of the rooster, the disease may not be transmitted unless the cells are present in the semen; but in the hen the cells may pass directly from the ovary into the developing ovule. This study was concerned primarily with transmission of the disease through the egg, but this may not be the only, or even the most important way it is transmitted.

338 The Effect of Processing on Vitamins in Fruits and Vegetables — A Review. C. R. Fellers. 23 pp.

Frozen, canned, and dried fruits and vegetables are very widely consumed and form a considerable proportion of the human dietary. The retention of the vitamins in these processed foods is of the greatest health interest. This bulletin sums up investigations carried on in other laboratories as well as extensive studies in this field of research at this station.

Control Bulletins

83 Sixteenth Annual Report on Eradication of Pullorum Disease in Massachusetts. Poultry Disease Control Laboratory. 8 pp. July 1936.

84 Inspection of Commercial Fertilizers. H. D. Haskins. 47 pp. October 1936.

85 Inspection of Commercial Feedstuffs. Philip H. Smith. 64 pp. October 1936.

86 Seed Inspection. F. A. McLaughlin. 81 pp. November 1936.

87 Inspection of Agricultural Lime Products. H. D. Haskins. 9 pp. December 1936.

Meteorological Bulletins

565–576, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. C. I. Gunness. 4 pp. each.

Reports of Investigation in Journals

Numbered Contributions

216 Resistance to *Cladosporium fulvum*. E. F. Guba. Phytopath. 16(4): 382–386. 1936.

The breeding of greenhouse tomatoes resistant to leaf mold is receiving attention in several countries, and it now appears probable that large-fruit tomatoes completely resistant to the disease will be developed.

221 The use of an electric steam generator for the sterilization of dairy utensils on the farm. H. G. Lindquist. Milk Plant Monthly, January 1936.

A small electric steam generator for sterilizing dairy utensils, now on the market, is described. It is simple in construction, easy to operate, and required about 0.85 KWH of current per hour. Utensils were rendered practically sterile in from 4 to 7 minutes, and dried out in a few minutes after removal from the sterilizer. It can be used without causing dust, dirt, or odors, and without any increase in fire hazard.

223 Nutritive value of the blue crab (*Callinectes sapidus*) and sand crab (*Platyonichus ocellatus* Latreille). Vernon K. Watson and Carl R. Fellers. Amer. Fisheries Soc. Trans. 65 (1935):342–349. 1936.

The sand crab and the blue crab are very similar in chemical composition and food value. The meat is a high-protein food, high in mineral content and alkalinity, and of medium calorific value. The protein of both species was approximately equal to beef protein in biological value.

224 Detection and significance of *Escherichia coli* in commercial fish and fillets. Francis P. Griffiths and James E. Fuller. Amer. Jour. Pub. Health 26(3):259–264. 1936.

Twenty-six commercial haddock fillets and five eviscerated haddock were bought at local retail markets and examined. Typical *Escherichia coli* were found on sixteen of the fillets and on two of the eviscerated fish. Further investigation is recommended, to study the possibility of using the occurrence of *Escherichia coli* as an index of the sanitary quality of marine fish and fillets.

226 Inheritance of sexual maturity in Rhode Island Reds. F. A. Hays. Sixth World's Poultry Congress, Berlin-Leipsic 2:34–38. 1936.

Crosses are reported within the Rhode Island Red breed, using an early-maturing production-bred strain and a late-maturing exhibition-bred strain. It was shown that early maturity depends upon dominant genes, both sex-linked and autosomal genes being involved. The earliest maturing phenotype results when both the sex-linked and the autosomal gene are present; the intermediate phenotype comes from the presence of either the sex-linked or the autosomal gene; and the late-maturing phenotypes are recessives lacking both dominant genes for early maturity.

229 Diagnosis of plant troubles with diphenylamine. Linus H. Jones. Plant Physiol. 11:207–209. 1936.

The diphenylamine test is frequently used as a means of determining a plant's need for nitrogen. Many tests made on different parts of plants showed in general that an actively growing plant part may give a negative test because the nitrate is being used in growth and therefore does not accumulate in the adjacent tissues; while older parts of the plant where active growth has ceased may give a positive test. The test is useful in diagnosing plant troubles only in cases where nitrates are involved.

230 The physiology of spermatozoa. Ralph W. Phillips. Amer. Soc. Anim. Prod. Proc. 1935:222–235. 1936.

A survey of the literature on the physiology of spermatozoa calls attention to the fact that knowledge is yet scanty in many phases of the problem. There is need for much further work, particularly with farm animals, in order to develop a sound basis for recommendations concerning the management and use of sires.

231 Chemical composition and fermentation studies of citron. C. R. Fellers and E. G. Smith. Jour. Agr. Research 53 (11):859–867. 1936.

The citron is characterized by high moisture; medium sugar, ash, and fat; and low fiber. Ash analysis shows moderate amounts of calcium, potash, phosphorus, and copper, but low iodine. The fresh unripe citron is very rich in vitamin C, but little is retained in the fermented citron and probably none in the candied peel. The vitamin A content is about 0.8 to 1 international unit in the green fresh citron and slightly less in the candied peel. The organisms responsible for the characteristic brine fermentation were the same as those previously reported for Corsican citron. A mixture of glucose and sucrose in the preserving syrups gave a better product than sucrose alone.

232 Time interval between eggs of Rhode Island Red pullets. F. A. Hays. Jour. Agr. Research 52 (8):633–638. 1936.

A short time interval between eggs during the winter months was found to be definitely associated with high annual egg production. The winter time interval appears to have value in predicting what the egg record may be at the close of the pullet laying year.

233 Microbiological examination of dried foods. J. A. Clague. Food Research 1 (1):45–59. 1936.

The number of organisms on dried foods varies from a few thousand per gram as a maximum on dried fruits to several millions per gram on dried vegetables. Artificial drying or dehydration was more effective in eliminating yeasts and materially reducing the numbers of bacteria and molds on fruits than on vegetables. The methods used in the commercial dehydration of foods, however, should produce a safe product, especially when it is considered that most of these foods are cooked before being eaten.

234 The efficiency of feed utilization in lambs. Ralph W. Phillips. Amer. Soc. Anim. Prod. Proc. 1935:161–163. 1936.

Marked variations exist in the efficiency with which lambs utilize feed. Definite conclusions regarding the inheritance of this efficiency cannot yet be drawn.

235 Vacuum determination in all-glass canning jars. W. A. Maclinn and C. R. Fellers. Food Research 1 (1):41–44. 1936.

The vacuum desiccator and the water displacement methods of determining the vacuum in all-glass preserving jars are described. Both methods are reasonably accurate, easy to manipulate, and have proved valuable in the laboratory examination of foods canned in glass.

236 Vitamin C content of raw, cooked, and canned rhubarb. J. A. Clague, C. R. Fellers, and Walter Stepat. Amer. Soc. Hort. Sci. Proc. 33:624–626. 1936.

Rhubarb is a good source of vitamin C. Fresh, cooked, and canned rhubarb yielded respectively 0.117, .032, and .016 mg of ascorbic acid per gram, corresponding to protective daily feeding levels (for guinea pigs) of 4.3, 9, and 22.7 grams.

237 Effect of shipping, freezing, and canning on the ascorbic acid (vitamin C) content of peas. C. R. Fellers and Walter Stepat. Amer. Soc. Hort. Sci. Proc. 33:627–633. 1936.

Cooked fresh and frozen peas are good sources of vitamin C. While the canning process has a more destructive effect on the ascorbic acid of peas than freezing, still enough remains in the canned product to constitute a fair source of C.

238 Effects of late summer and fall applications of nitrogen on fruit production in the strawberry. R. A. Van Meter. Amer. Soc. Hort. Sci. Proc. 33:401–404. 1936.

There is little indication that summer and fall applications of nitrogen were in any way either significantly beneficial or injurious under the not unusual conditions surrounding these experiments.

239 The Malling Clonal stocks in relation to McIntosh and Wealthy. J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 33:346–349. 1936.

Whether any of these "standard" clonal stocks are enough superior to good seedling stocks to warrant their general use is yet debatable.

240 A comparative study of certain presumptive media for testing raw waters. Ralph L. France. Jour. Amer. Water Works Assoc. 28 (6):785–793. 1936.

The use of lactose broth with confirmation of all positive presumptive tubes by inoculation into secondary tubes of B.G.B. broth gave the highest total number of recoveries of the coli-aerogenes group from the raw waters tested. The results indicate that this method may prove the most satisfactory for testing raw polluted waters.

241 Some studies on the forcing of Delphinium. Harold E. White. Amer. Soc. Hort. Sci. Proc. 33:653–564. 1936.

Delphinium Belladonna can be stored at a temperature between 32° and 38° F. for eight weeks early in the summer and be forced into bloom for November or December.

Plants which have flowered apparently will not bloom again until they have been chilled, or at least they require a rest period longer than is practical for commercial purposes.

243 Vitamin-C content of dairy orange beverages. M. J. Mack, C. R. Fellers, W. A. Maclinn, and D. A Bean. Food Research 1 (3):223 230. 1936.

While some dairy orange beverages are fair antiscorbutics, they contain on the average only one-tenth as much vitamin C as fresh orange juice, and many cannot even be considered satisfactory substitutes for fresh or canned orange juice as carriers of vitamin C.

244 Numbers and uniformity in experimental lots. F. A. Hays. Poultry Sci. 15 (3):235–238. 1936.

When annual egg production is used as the measure of experimental results, 100 birds may constitute a fair sample in an improved flock, while considerably greater numbers are necessary in stock not bred for high fecundity. Standard constants, probable errors of means or of single determinations, can all be calculated with accuracy when each experimental lot represents a fair sample.

245 Oxidation-reduction potentials of soil suspensions in relation to acidity and nitrification. M. C. Darnell, Jr., and W. S. Eisenmenger. Jour. Agr. Research 53 (1):73–80. 1936

Any change of potential with nitrification is secondary to the effect of nitrification on pH. The addition of sulfate of ammonia or nitrate of soda was found to have no constant effect on the potentials of suspensions of the soils. The rapid decomposition of organic matter brought about a marked fall of potential, apparently due to oxygen depletion.

246 The indol tolerance of certain strains of the colon-aerogenes group. Ralph L. France. Jour. Bact. 32 (2):211–214. 1936.

The object of this study was to determine whether there existed a sufficiently wide variation in the indol tolerance of the various members of the coli-aerogenes group to be of practical value. No such variation was found, however.

247 A comparison of the chemical composition of pasture grass with a mixed concentrate. Emmett Bennett. Jour. Dairy Sci. 19 (9):623 629. 1936.

Results indicate that for the dairy cow the dry matter of pasture grass in the vegetative state is comparable with concentrated feeds, and that its chemical composition can be so changed by the application of fertilizer that it approaches a nitrogenous concentrate in character.

250 Susceptibility of different strains of rats to nutritional cataract. Helen S. Mitchell. Jour. Nutr. 12 (5):447–453. 1936.

Variations in the incidence of cataract in different strains of rats and at different ages emphasize the necessity for a consistent experimental procedure, a relatively large number of observations, and a consideration of the susceptibility to cataract of the strain of rats used. It is quite possible that breed differences in the rats may account for the apparent discrepancy in observations from various laboratories.

251 Studies on the inheritance of persistency. F. A. Hays. Genetics 21:519–524. 1936.

Results from crossing high and low persistency lines of Rhode Island Reds show that the dividing point between high and low persistency phenotypes lies close to 270 days. That high persistency depends in inheritance upon a single dominant autosomal gene is confirmed. In breeding operations it is recommended that the standard for selecting breeding stock for high persistency be placed well above a 270 day minimum, because of overlapping in phenotpyes.

252 Milk Drinks. J. H. Frandsen. Milk Plant Monthly. June 1936.

Directions are given for making a number of milk drinks which are wholesome, appetizing, and easily prepared.

255 Sodium alginate as a stabilizer in manufacturing ice cream. M. J. Mack. Ice Cream Trade Jour. November 1936.

Ice cream mixes containing sodium alginate were relatively uniform in viscosity, whipped readily to the desired overrun during the freezing process, and produced a finished ice cream of smooth texture and desirable melting characteristics. Sodium alginate, therefore, appears to be a satisfactory stabilizer when properly incorporated into the mix.

258 Bacteriological examination of glassware or china for sanitary quality. C. R. Fellers, A. S. Levine, and E. W. Harvey. Amer. Jour. Pub. Health 26 (12):1211–1214. 1936.

A comparison of various methods for the bacteriological determination of the sanitary condition of drinking glasses and eating utensils showed the swab method to be the most satisfactory. Practical tests of the method showed it to be rapid, simple, and reliable. It should prove useful to health laboratories as a routine method for checking the cleansing and sterilization of utensils in establishments dispensing food and beverages.

260 Composition and nutritive studies on blueberries. Oreana A. Merriam and Carl R. Fellers. Food Research 1 (6):501-512. 1936.

Analyses of fresh and moisture-free wild and cultivated blueberries are reported. The fruit contained from 1 to 2 units of vitamin C and about 1 unit of vitamin A per gram. Frozen blueberries contained as much vitamin C as fresh, but defrosting was destructive to this vitamin. Canning partially preserved the vitamin C. Blueberries contained only a trace of benzoic acid. When fed in 300-gram amounts to young men, they did not lower the blood alkali reserve, nor did they increase urinary acidity.

262 Cytospora canker of spruces. C. J. Gilgut. Twelfth Natl. Shade Tree Conf. Proc. 1936.

The dying of the lower limbs of Colorado blue spruce, long considered a natural occurrence due to age, is here shown to be caused by the fungus, *Cytospora Kunzei*. The disease was produced artificially by inoculation, but infection occurred only when wounds were made in the bark. This is the most serious disease of Colorado blue spruce and Norway spruce in Massachusetts, where these trees are used extensively as ornamentals.

Other Contributions to Journals

Unnumbered

Vinegar as a soil disinfectant. William L. Doran. Science 84 (2177): 273–274. 1936.

Notes on carnation blight and wilt. E. F. Guba. Flor. Ex. and Hort. Trade World. March 7, 1936.

Science contributes to greenhouse tomato industry. E. F. Guba. Flor. Ex. and Hort. Trade World, p. 21. October 24, 1936.

Moist mats for clay pots. Linus H. Jones. Flor. Ex. 86 (15): 11. 1936.

Fighting drought in the flower pot. Linus H. Jones. N.Y. Times, Sunday, Section 9:12. July 5, 1936.

Flood injury to trees. Malcolm A. McKenzie. Science 83:412:413. 1936.

Shade tree diseases of New England. Malcolm A. McKenzie. Twelfth Natl. Shade Tree Conf. Proc. 1936.

Shade tree diseases. Malcolm A. McKenzie. Amer. Nurseryman 64 (10): 7–8. 1936.

Fruit insects in Massachusetts in 1935. A. I. Bourne and W. D. Whitcomb. Mass. Fruit Growers' Assoc. Ann. Rpt. 1936.

Fungus infesting onion thrips. A. I. Bourne and F. R. Shaw. Bul. Brooklyn Ent. Soc. 31 (1):15–16. 1936.

Codling moth, curculio, and apple maggot. A. I. Bourne. (Address, Amer. Pom. Soc.). Conn. Pom. Soc. Rpt. May, 1936.

Insects found to be pollinating onions. A. I. Bourne and F. R. Shaw. Amer. Bee Jour. 76 (8): 401–402. 1936.

Lead arsenate for the control of turf insects. W. D. Whitcomb. Mass. Golf Assoc. Diary. 1936.

Some observations on the overwintering habits of the American elm bark beetle. W. B. Becker. Jour. Econ. Ent. 28 (6): 1061. 1935.

Spathius canadensis — a parasite of *Hylurgopinus rufipes*. W. B. Becker. Jour. Econ. Ent. 29 (4):807. 1936.

Ascorbic acid (vitamin C) content of lima beans as affected by shipping, freezing and canning. (Abstract.) C. R. Fellers, Walter Stepat and G. A. Fitzgerald. Jour. Bact. 32:359–360. 1936.

Report of treatment of unopened container (for bacteriological examination of canned foods). C. R. Fellers. Jour. Assoc. Off. Agr. Chem. 19:430–431. 1936.

The influence of certain fruits in the diets of rats on the fecal flora and intestinal reaction. (Abstract.) W. B. Esselen, Jr. Jour. Bact. 32:359. 1936.

Vitamin C content of dairy orangeades. M. J. Mack, C. R. Fellers, W. A. Maclinn and D. A. Bean. Milk Plant Monthly 25(8):52–55. 1936.

Cranberries for health. C. R. Fellers. Natl. Cran. Mag. 1 (3):12–13. 1936.

Vitamin content of important foods. C. R. Fellers. Dental Survey 12 (3): 44–49. 1936.

LIST OF AVAILABLE BULLETINS

213 Tobacco wildfire
216 Digestion experiments with cattle feeds
229 Soil reaction and black root-rot of tobacco
237 Liming onions
243 The McIntosh apple on the New York market
245 Blight and leaf-spot of carrot in Massachusetts
246 Control of red spider and powdery mildew on greenhouse cucumbers
247 Biennial Report for 1927–1928
255 Studies in mineral nutrition
256 The cost of government in Massachusetts
260 Annual report for the fiscal year ending November 30, 1929
261 Ecological studies of the Mexican bean beetle
263 Food service in Massachusetts rural elementary schools
265 A chemical study of cranberries
270 Meteorological records — a forty-year summary, 1889–1928
271 Annual report for the fiscal year ending November 30, 1930
274 The identification of apple varieties from non-bearing trees
275 Planning the farm business on three dairy–fruit farms in Massachusetts
276 Increasing soil acidity as a means of controlling black root-rot of tobacco
278 Infectious laryngotracheitis
280 Annual report for the fiscal year ending November 30, 1931
282 Relation between egg quality and price
283 Downy mildew of cucumbers
284 Questions and answers concerning pullorum disease
285 The relation of temperature to the activity and control of the plum curculio in apples
287 Frozen fruits and their utilization in frozen dairy products.
288 The relation of feather pigmentation to intensity of laying in Rhode Island Reds
289 Hereditary and environmental factors affecting variability in egg production
290 The story of Field A of the Massachusetts Agricultural Experiment Station: A review of experiments with nitrogen fertilizers
291 Two systems of feeding dairy cows: High roughage and low grain versus low roughage and high grain
292 Carbon disulfide emulsion for the control of the root-knot nematode
293 Annual report for the fiscal year ending November 30, 1932
295 The immunology of infectious laryngotracheitis
296 Effect of manufacturing and preserving processes on the vitamins of cranberries
297 The effect of certain cropping systems on the yield and quality of Havana tobacco
298 The significance of length of laying year in production breeding
299 Shipping Massachusetts apples to out-of-state markets
300 Chemical composition of herbage from Massachusetts pastures
301 Characteristics of non-broody and intense broody lines of Rhode Island Reds

302 Higher aging temperatures in the manufacture of ice cream
303 Effect of hydrocyanic acid gas on cucumber plants previously sprayed with copper fungicides
304 Secondary milk markets in Massachusetts in the period of falling prices, 1930–1932
306 Fertilizer tests on an important pasture soil type
308 Preliminary studies on neurolymphomatosis and some more or less related diseases
309 Soybeans for Massachusetts
310 Supplementary mid-morning feeding of rural school children.
311 Infectious laryngotracheitis vaccination
312 Effects of inbreeding on fecundity in Rhode Island Reds
313 Time interval from first egg to standard egg weight in Rhode Island Red pullets
314 Effect of aging treatment on the bacterial count of ice cream mixes
315 Annual report for the fiscal year ending November 30, 1934
316 Crossing production and exhibition Rhode Island Reds
317 Blueberry culture in Massachusetts
318 Onions in the Connecticut Valley
320 Pruning bearing apple trees
321 Tankage as a source of protein for dairy cows
322 The effect of fertilizers on the longevity of mowings
324 Potash in Massachusetts soils: Its availability for crops
325 Poultry flock improvement
326 Naphthalene as a greenhouse fumigant
327 Annual report for the fiscal year ending November 30, 1935
328 Heavy mulching in bearing apple orchards
329 Winter pause in Rhode Island Reds
330 The bulbous iris and its outdoor culture in Massachusetts
331 The development of the testes and scrotum of the ram, bull, and boar
332 The cranberry industry in Massachusetts
333 A study in soil nitrogen
334 Dried blood as a source of protein for dairy cows
335 Some factors affecting the properties of whipping cream and the quality of the finished product
336 Apple cider and cider products
337 Observations and experiments with neurolymphomatosis and the leukotic diseases
338 The effect of processing on vitamins in fruits and vegetables — a review

Control Series

83 Sixteenth annual report on eradication of pullorum disease in Massachusetts, 1935–1936
84 Inspection of commercial fertilizers for the season of 1936
85 Inspection of commercial feedstuffs (1936)
86 Seed inspection (1936)
87 Inspection of agricultural lime products for the season of 1936

Meteorological Bulletins

Monthly bulletins available back to the last summary (Bul. 270), January 1929.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
3m. 3–'37. No. 40

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 340 January, 1938

Historical Trend in Massachusetts Industries

1837 - 1933

By David Rozman and Ruth E. Sherburne

MASSACHUSETTS STATE COLLEGE
NATURE GUIDE'S LIBRARY
FERNALD HALL
This material is loaned for your convenience.
Please return promptly.

In Massachusetts as in many other states, there have occurred over a period of years shifts in population and in the distribution of industries between individual cities and towns of various sizes. This publication presents a graphic summary of the changes in population, number of industrial employees, and number of industrial establishments during the last hundred years, for those cities and towns of the Commonwealth where the historical data are available.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

HISTORICAL TREND IN MASSACHUSETTS INDUSTRIES
1837 - 1933

By David Rozman, Research Professor, and Ruth E. Sherburne,
Research Assistant, in Economics

This is an attempt to present in graphic form the most essential data in connection with trends of industrial development in Massachusetts cities and towns. The statistics in this volume are presented in a series of charts indicating the trend of population, number of manufacturing establishments, and number of employees[1] for 142 cities and towns, beginning with 1837 or a later date as statistics became available.

STATISTICS FOR CITIES AND TOWNS

This statistical presentation of historical trends for individual cities and towns is based on the Massachusetts State Census, the Federal Census of Manufactures and the Annual Reports of the State Department of Labor and Industries. Of the three items presented in these historical charts, the number of establishments, number of employees, and population, only the last one is based on uniform and consistent data throughout the period.

In considering the trend in number of establishments and employees it is essential to keep in mind that there have been some changes in the definition of the manufacturing unit from one census to another. Consequently, throughout the period for which statistics are presented, suitable allowance was made for the variations introduced in different periods in the method of calculations. With these corrections it is believed that the figures as presented, even though not absolutely accurate, are fairly comparable and with a few exceptions present an adequate picture of the development which has taken place in individual localities. The bases adopted from one census to another in the matter of enumerating the industries are as follows: In the State Census of 1837 a list of industries on which returns were to be made was definitely stated in the Act. This definition was carried out consistently in the Censuses of 1845, 1855, 1865, and 1875.

In the Census of 1885 a new division was introduced — Food Preparation. Inasmuch as this had reference mostly to farm production and was not included in the totals for the preceding period, this item was omitted from subsequent calculations in order to make the statistics comparable and consistent.

The figures from the 1895 Census as incorporated in the charts present the number of employees for that week in the year when the employment was at its highest point, as compared with other censuses when employment was given as of a certain date.

Beginning with the Census of 1905, the census authorities adopted the general principle of not disclosing the figures for individual towns where the number of industries was small or where the disclosure of figures might be equivalent to identification of individual industries. As a result it has not been possible to obtain historical statistics for all towns up to the present time. Out of a total of 355 Massachusetts cities and towns, there were only 142 with statistics available from 1837, or from the time they became qualified, up to recent years.

---

[1] In this bulletin the term "employees" should be understood as confined to wage-earners.

About 200 towns are not included in the graphic presentation, either because they had no industries to qualify for census enumeration or because the figures were given for a very limited period of time or because they had some irregularities which made them inadequate for presentation.

Because of the lack of adequate State figures, the statistics from 1905 to 1927 were compiled on the basis of the United States Census of Manufactures. The Federal Census differed from the State Census by omission of the following: (1) Establishments idle throughout the year or reporting products valued at less than $500; (2) those industries engaged principally in work for individual customers; (3) building industries other than those manufacturing building materials for general trade; (4) neighborhood industries, hand trades in which little or no power machinery was used; (5) cotton ginneries; (6) small grain mills; (7) wholesale and retail stores which incidentally manufactured on a small scale; (8) educational and penal institutions. The Biennial Census of Manufactures and the Annual Report of the Department of Labor and Industries of Massachusetts adopted the principle of enumerating only those establishments which reported products to the value of $5,000 or more.

In general, the tendency from one period of enumeration to another has been to eliminate from consideration some very small establishments — small shops either representing a purely family affair or having not more than one or two employees. For most of the towns the general trend in the number of industrial establishments was upward until 1895. From 1905 to the end of the period very few towns added to the number of establishments, most of them either remaining stable or showing a decline. A sharp decline in the number of establishments between 1895 and 1905, as registered on the charts, is due primarily to the change in the statistical basis of the census enumeration, which should be taken into consideration in interpreting that period.

The actual trend of industrial development in individual towns is shown more adequately by the curve representing the number of employees. This gives a more accurate idea of what happened in individual towns, inasmuch as elimination of small industries with one or two employees does not affect considerably the general trend in the total number of employees.

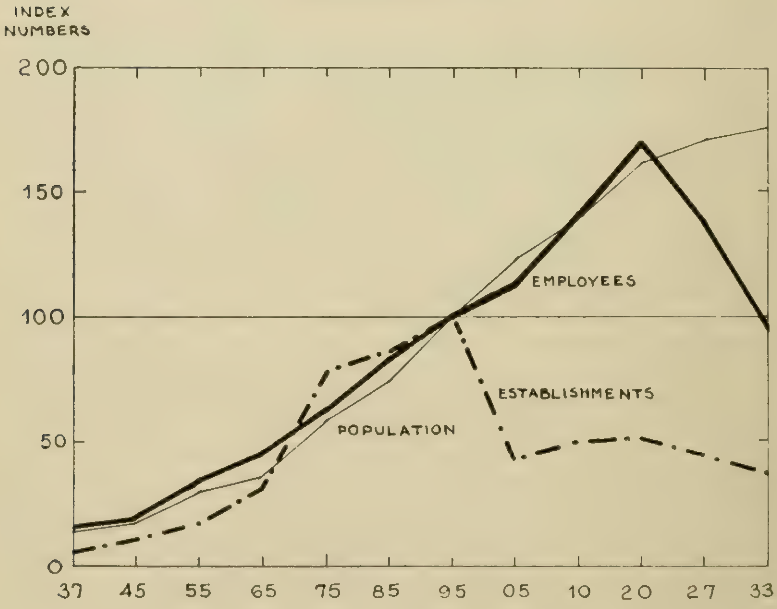
In presenting the historical trend of the several items connected with the industries the index method seemed to be the best, inasmuch as the absolute figures differed widely from one city or town to another, and would require the introduction of different scales on the charts. The year 1895, indicated as 100, was taken as the base period whenever figures were available. This was about the middle point of the period, and was in many cases the turning point as far as the number of employees and establishments was concerned.

All Cities

From the chart portraying the changes in population, number of industrial employees, and establishments in Massachusetts cities, it will be seen that there has been a continuous upward trend in population. The number of industrial employees displays the same upward tendency, closely paralleling the population curve until 1920. Since that date there has been a decisive decline in the number of industrial employees, especially in the period between 1927 and 1933, emphasized by the intervening years of business depression. The number of establishments was on the upward trend until 1895. Due to the change in the statistical enumeration there was a sharp decline in the number of establishments between 1895 and 1905. From 1905 there was a slight upward trend to 1920, since when a declining movement has been in progress to the end of the period.

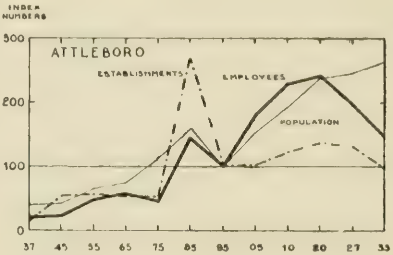
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100

THIRTY-NINE CITIES

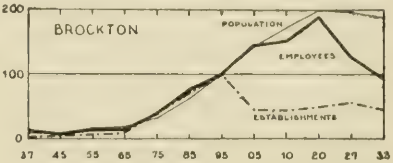


Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100

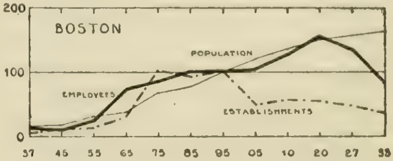
Attleboro. After 1885 North Attleboro was separated from Attleboro, and this was reflected in a drop of all indexes by 1895. Since that time all three items have increased, with the number of industrial establishments and employees beginning to decline after the peak of 1920.



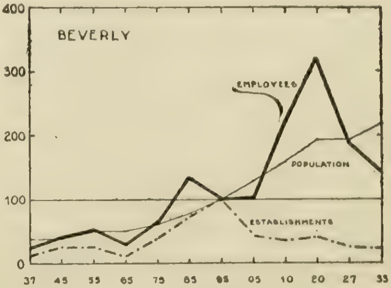
Brockton. In Brockton as in Lynn, Haverhill, and other cities where the shoe industries are prominent, a general decline in the number of employees and industries has occurred since 1920, due to unfavorable competitive conditions. The peak in population and industrial employment was reached in 1920, after which the number of employees declined at a more rapid rate than population. The number of establishments has shown a slight upward trend since 1905.



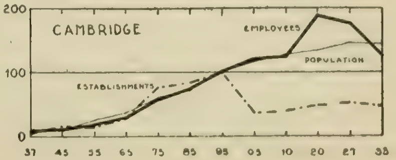
Boston. Both number of industrial employees and population have been increasing since the beginning of the period. The former, however, reached its peak in 1920, after which there was a decline. The number of establishments declined from 1895 to 1905, due mostly to the change in the basis of enumeration previously noted. Since 1910 there has been a slight downward trend in the number of establishments.



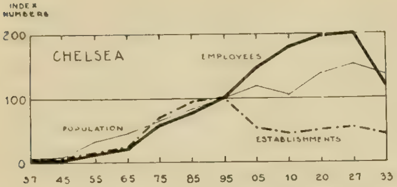
Beverly. With an upward trend in both population and number of industrial employees, the latter showed a very rapid growth from 1905 to 1920. Since then the number of employees has declined, while the population has continued to grow. The number of industrial establishments reached its peak in 1895 and has been on an irregular decline ever since.



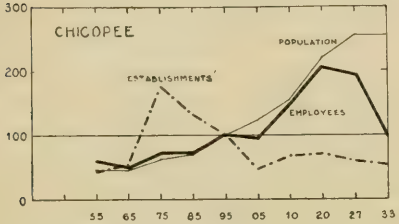
Cambridge. With an upward trend throughout the period, the number of industrial employees shows a more rapid increase than does population between 1910 and 1920. Since then the number of employees has been declining, but population has continued with a slight upward trend. The number of industrial establishments was higher in 1933 than in 1905.



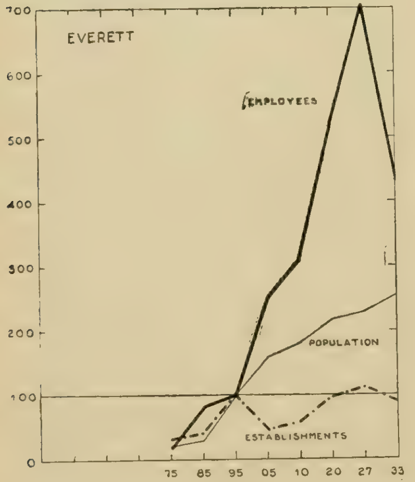
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100



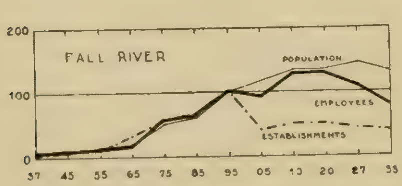
Chelsea. The population and number of industrial employees show an upward trend to 1927. During the period of depression both of the indexes showed a decline. The number of establishments at the end of the period was about the same as in 1905.



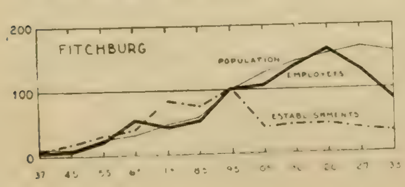
Chicopee. Since 1895 the total population has shown a higher rate of increase than the number of industrial employees. The latter reached its peak in 1920 since when it has declined. The number of establishments was at its highest in 1875 and at the end of the period was slightly higher than in 1905.



Everett. The number of industrial employees increased very rapidly from 1875 up to the beginning of the depression. The trend of total population has also been upward, but at a lower rate than the number of industrial employees. The number of industrial establishments increased from 1905 to 1927.



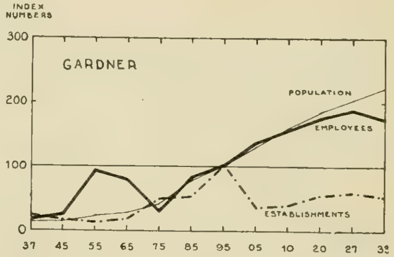
Fall River. In Fall River as in a number of other cities like Lowell and New Bedford where the textile industries are prominent, a general depression has been in progress since 1920, due to the depression in the textile industry and general unfavorable competitive conditions. After an upward trend from the beginning of the period, the number of industrial employees declined sharply following 1920, and total population showed its first decline between 1927 and 1933. The number of industrial establishments has not changed greatly between 1905 and the end of the period.



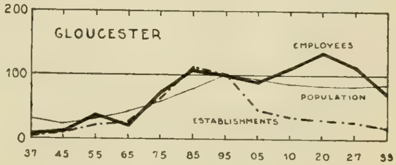
Fitchburg. The number of industrial employees reached its peak in 1920 and population in 1927. The number of industrial establishments increased slightly between 1905 and 1920, followed by a slight decline.

Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100

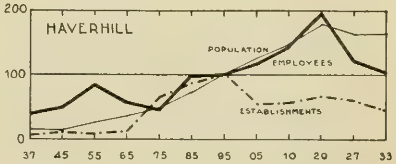
Gardner. The total population and number of industrial employees have shown a strong upward trend since 1875. The index of industrial employment shows a slight decline between 1927 and 1933. The number of industrial establishments has been on the increase since 1905, except in the period between 1927 and 1933.



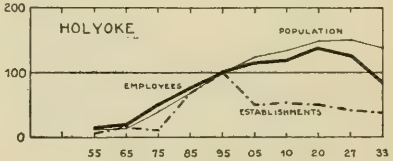
Gloucester. The peak of industrial employment was reached in 1920, but total population shows a slight downward trend from 1895 until 1927. This decline was evidently caused by a falling off in the fishing industry. The number of industrial establishments has been declining since 1885.



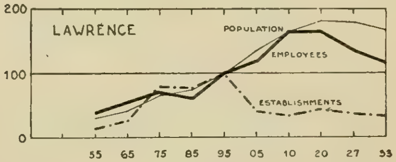
Haverhill. After reaching their height in 1920, both the number of industrial employees and the total population declined. The latter increased slightly between 1927 and 1933. The number of industrial establishments increased between 1905 and 1920, then declined to the end of the period.



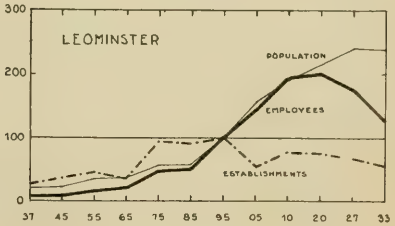
Holyoke. With an upward trend since 1855, the number of industrial employees reached its peak in 1920 and the total population in 1927. The number of industrial establishments was slightly lower in 1933 than in 1905.



Lawrence. After a rise for several decades the number of industrial employees began to decline in 1910 and the total population in 1920. The number of industrial establishments has not changed greatly for the last 30 years.

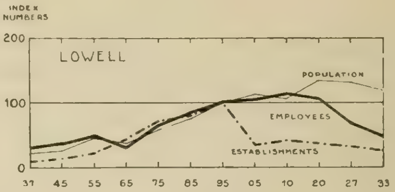


Leominster. The peak of industrial employment was reached in 1920 and that of population in 1927. The number of industrial establishments has been declining since 1910.

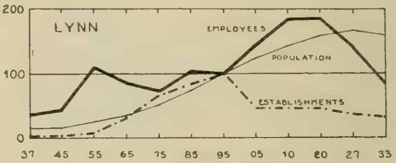


Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100

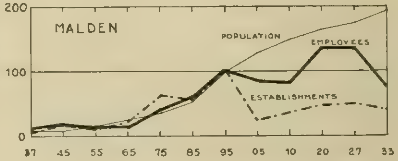
Lowell. The number of industrial employees began to decline in 1910, falling sharply between 1920 and 1933. The total population started a slight downward trend in 1920. The number of industrial establishments was slightly lower in 1933 than in 1905.



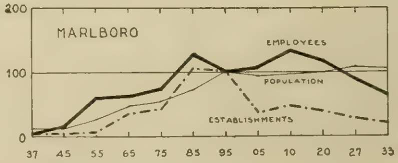
Lynn. There was a rapid rise in the number of industrial employees between 1895 and 1910, and an equally sharp decline between 1920 and 1933. The upward trend of population stopped in 1920 after which there was a slight decline. The number of industrial establishments increased rapidly between 1855 and 1895. It was slightly lower in 1933 than in 1905.



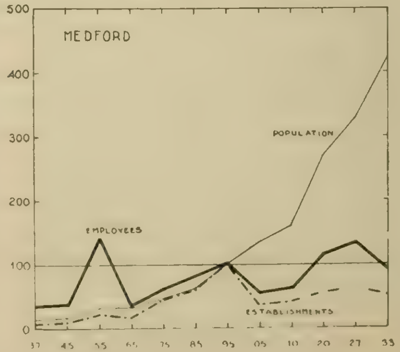
Malden. The trend of total population has been upward throughout the period beginning with 1845. The number of industrial employees rose sharply between 1910 and 1920. A considerable decline occurred in the period of depression. The number of establishments has risen somewhat since 1905.



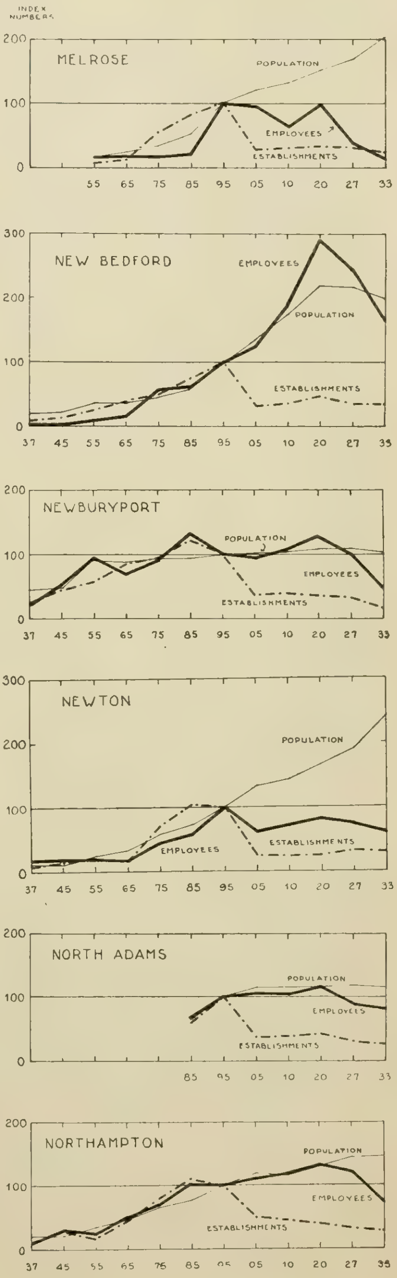
Marlboro. After an irregular rise the number of industrial employees began its decline in 1910. The total population has not changed greatly since 1895, being now only slightly higher. The peak in number of establishments was reached in 1885.



Medford. There has been a rapid increase in total population, especially since 1910, evidently promoted by elements other than industrial growth. Industrial employment reached its peak as early as 1855, and in 1933 it was at about the same level as in 1895. There was, however, an upward trend in industrial employment as well as in the number of industrial establishments between 1905 and 1927.



Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100



Melrose. The population has shown an upward trend throughout the period, but the number of industrial employees reached its peak in 1895, duplicated it in 1920, and then declined sharply. The number of establishments increased until 1895, and has remained nearly stationary since 1905.

New Bedford. Both population and number of industrial employees reached the peak of their upward trend in 1920, and since then there has been a slight decline in the former and a rather sharp decline in the latter. The number of establishments increased up to 1895, and again between 1905 and 1920.

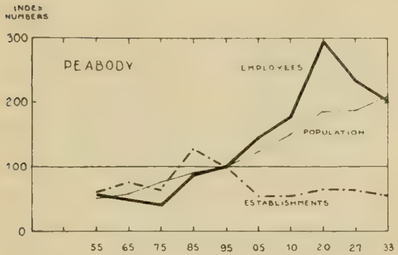
Newburyport. The population has shown only a slight increase since 1895. The number of industrial employees reached its peak in 1885, declined for the next 20 years, then showed an upward trend until 1920, followed by a sharp drop in 1927 and 1933. The number of industrial establishments has been declining since 1885.

Newton. The population has maintained a strong upward trend throughout the period; but the number of industrial employees, after reaching its peak in 1895, declined to 1905, and has remained with slight variations at about the same level. There was a slight upward movement in the number of industrial establishments.

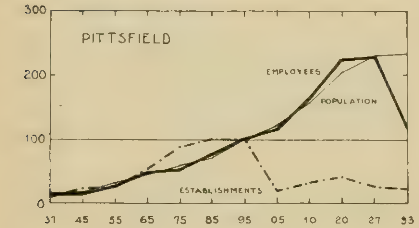
North Adams. After a sharp increase from 1885 to 1895, the population and number of employees showed a slight upward movement until 1920; since that time the former has remained at about the same level, while the latter has considerably declined. The number of establishments had a slight upward trend between 1905 and 1920, beginning to decline after that date.

Northampton. Both population and number of industrial employees had an irregular upward trend, but the latter began to decline after the peak of 1920. The number of industrial establishments has been declining since 1885.

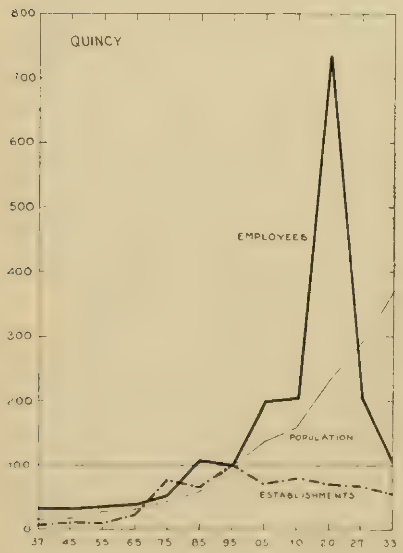
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100



Peabody. With population and number of industrial employees on an upward trend, the latter showed a very sharp increase from 1895 to 1920 after which it went into a considerable decline. The number of industrial establishments was at its peak in 1885, and in 1933 kept at about the same level as in 1905.



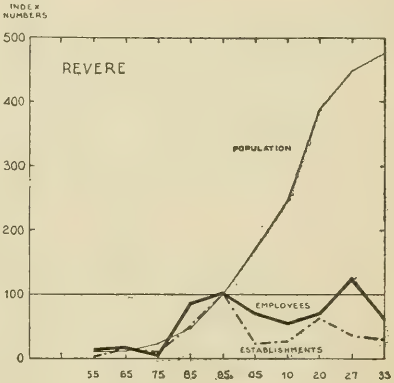
Pittsfield. The upward trend in population and number of industrial employees has been maintained through the entire period, except that the latter showed a sharp decline after 1927 coinciding with the period of depression. The number of industrial establishments increased from 1905 to 1920 and declined afterwards.



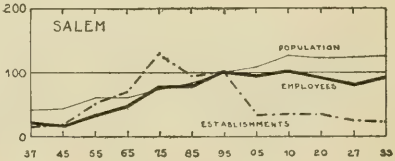
Quincy. The population increased rapidly through the entire period; and the number of industrial employees, after an extremely sharp rise, largely due to activities of war industries between 1910 and 1920, broke down thereafter into a rapid decline, and in 1933 was at about the same level as in 1895. The number of industrial establishments was only slightly lower in 1933 than in 1905.

Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100

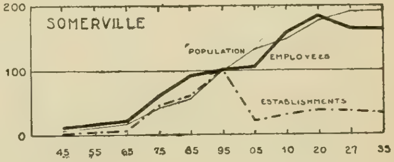
Revere. There was a very rapid increase in total population through most of the period, evidently due in large part to residential and recreational developments. The number of industrial employees had an irregular trend, rising until 1895, declining to 1910, reaching its peak in 1927, and declining again during the depression period. The number of industrial establishments increased from 1905 to 1920 and declined thereafter.



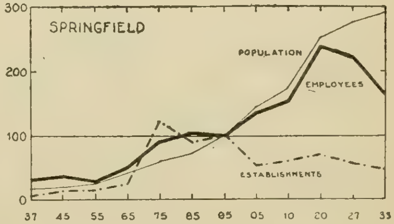
Salem. The population, after an irregular rise, reached its peak in 1910 and remained practically stationary thereafter. The number of industrial employees rose irregularly until 1910, declined thereafter up to 1927 and unlike many other cities, showed an increase in 1933. The number of industrial establishments, with a few minor interruptions, has shown an irregular downward movement since 1875.



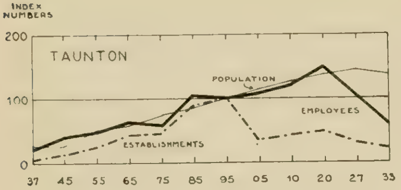
Somerville. There has been a steady upward movement in population through the entire period; while the number of industrial employees increased until 1920, declined in 1927, and showed no change in 1933. Between 1905 and 1920 there was an increase in number of industrial establishments and a slight decline thereafter.



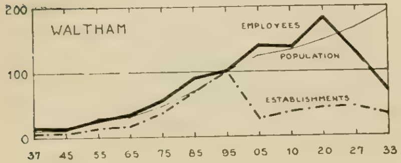
Springfield. The population maintained a regular upward movement during the entire period; while the number of industrial employees, after a long advance, began to decline in 1920. The increase in number of industrial establishments between 1905 and 1920 was followed by an almost equal decline.



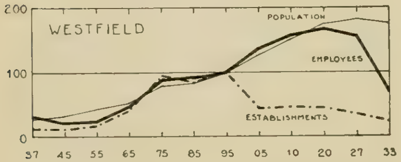
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100



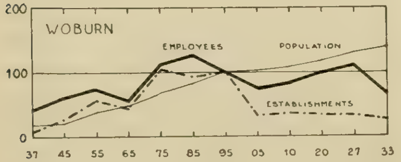
Taunton. After a long upward movement the population showed a slight decline in 1933; and the number of industrial employees, after reaching its peak in 1920, declined sharply to the end of the period. The index for industrial establishments followed the same trend as the number of employees between 1905 and 1933.



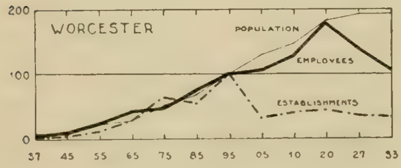
Waltham. The upward movement in the total population was maintained to the end of the period, while the number of industrial workers went into a sharp decline after 1920. The total number of establishments was in an upward movement from 1905 to 1927 and declined slightly afterwards.



Westfield. After a long upward trend the population has shown a slight decline since 1927, while the number of industrial employees began its decline in 1920. There has also been a downward trend in the number of establishments since 1920.



Woburn. The population has shown an upward trend during the entire period; but the number of industrial employees reached its peak in 1885, declined during the next 20 years, increased considerably between 1905 and 1927, and again declined during the depression years. The number of establishments has not changed greatly since 1905.



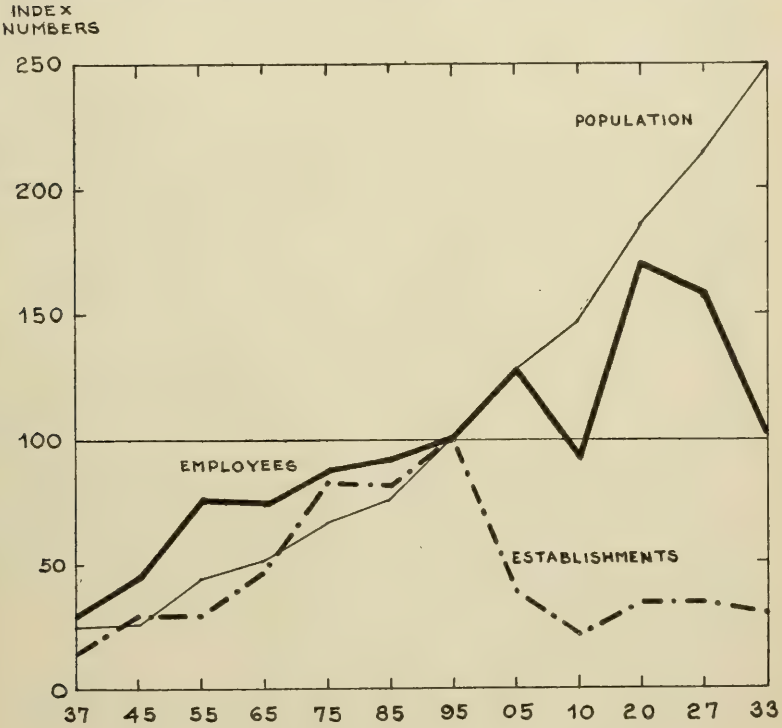
Worcester. The upward trend of population continued to the end of the period, while the number of industrial workers declined considerably after 1920. After 1905 the number of establishments followed the trend of industrial workers, with slight fluctuations.

Thirty-four Towns Having over 10,000 Population in 1930

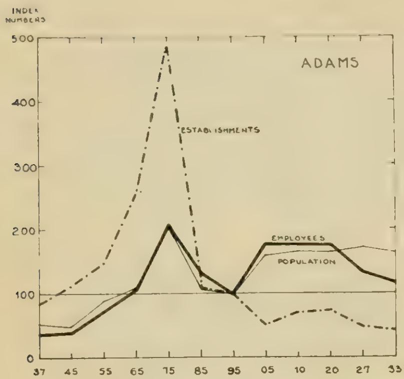
In the towns with a population of 10,000 or over there has been a constant increase in population through the entire period under consideration. The number of industrial employees kept up with the increased population until 1905, but dropped considerably in 1910. After that date there was recovery until 1920, with a subsequent decline bringing down the index in 1933 to a level only slightly higher than it was in 1910. The number of industrial establishments has been moving in general in the same direction as the number of industrial employees, except for the period between 1895 and 1905, which as stated above, reflects the change in the statistical enumeration.

Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100

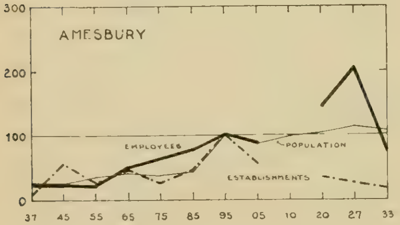
THIRTY-FOUR TOWNS WITH OVER 10,000 POPULATION IN 1930



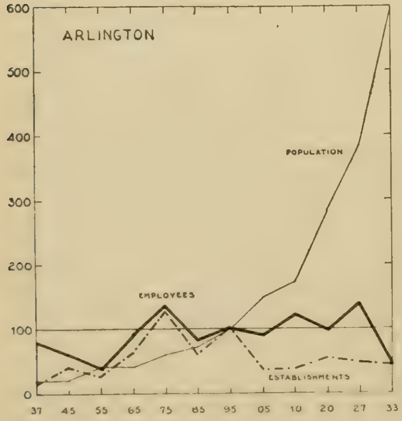
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100



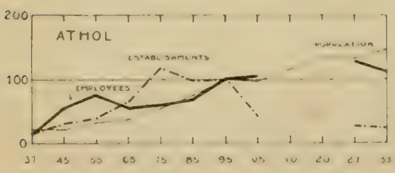
Adams. A sharp decline of all three items in this town after 1875 is due to the separation of North Adams which became an independent town. Since 1885 the number of establishments has shown an irregular decline, while the number of employees began its decline after 1920.



Amesbury. The number of employees and population reached their peak in 1927 after which there was a decline. The number of establishments has constantly declined since 1895.



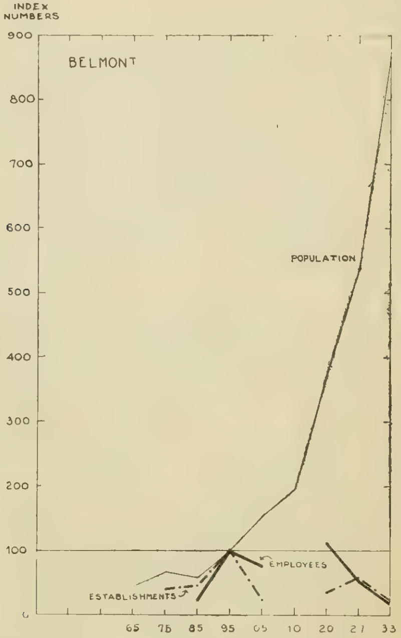
Arlington. The town has developed into an urban community with a rapid increase in population during the last 40 years. The number of establishments reached a peak in 1875, but the number of employees reached a slightly higher peak in 1927 than in 1875.



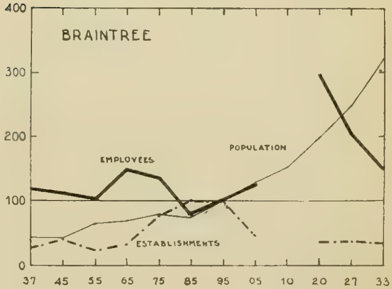
Athol. Population has been increasing almost throughout the period. The number of employees also has been increasing through most of the period, but at a very slow rate.

Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100

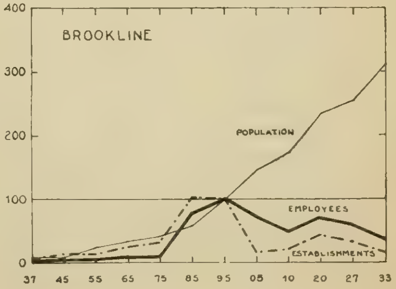
Belmont. The population has been increasing rapidly, but the number of industrial employees has declined since 1920.



Braintree. The number of employees shows an upward trend until 1920 with a decline thereafter, while the population continued to increase throughout the period.

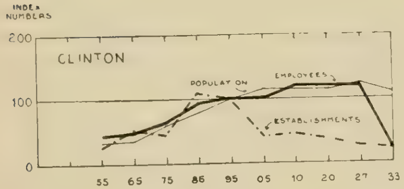


Brookline. As in other urbanized towns population has increased rapidly, while the number of establishments and employees has shown a downward tendency since 1895.

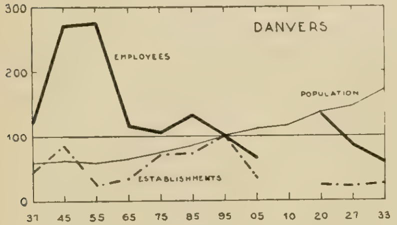


Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933

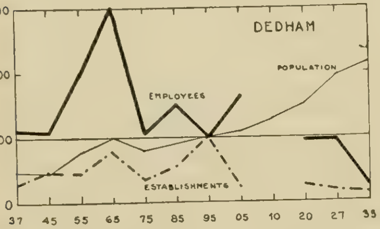
1895 = 100



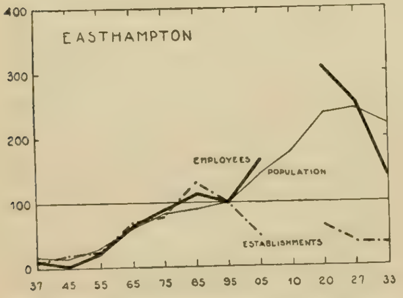
Clinton. The population and number of employees reached their peak in 1927 after which the latter shows a considerable decline.



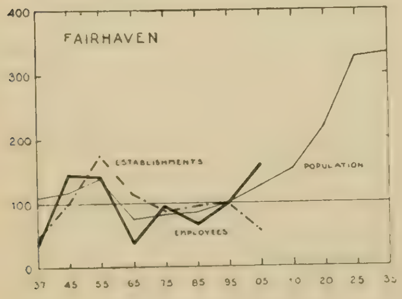
Danvers. The population shows an upward trend, but the peak of industrial development was reached in the middle of the last century.



Dedham. The highest level of industrial employment was reached in 1865. The population has been increasing through practically the entire period.



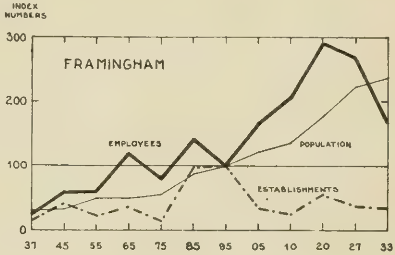
Easthampton. The highest point of industrial employment was reached in 1920. Population shows a decline after 1927.



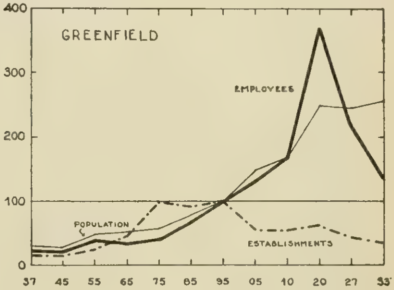
Fairhaven. Data on the number of establishments and employees are available only to 1905. Population has been constantly increasing since 1865.

Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100

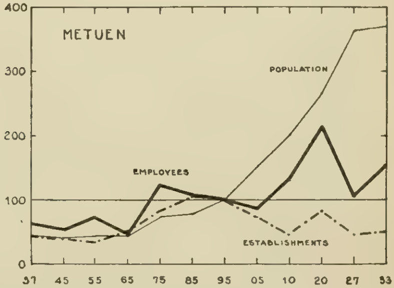
FRAMINGHAM. The highest point of industrial employment was reached in 1920. Population has been increasing throughout the period.



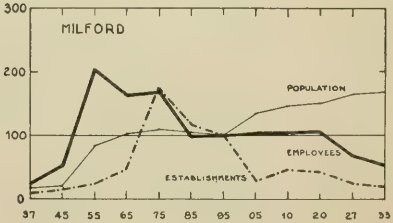
GREENFIELD. The number of employees increased very rapidly until 1920. Since then there has been a sharp decline.



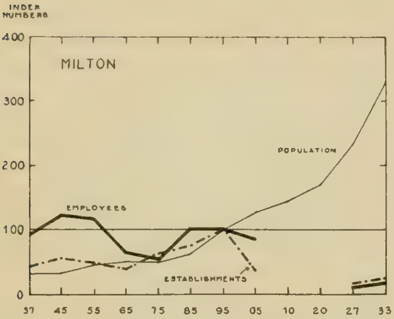
METHUEN. The peak of industrial employment was reached in 1920. There were more employees in 1933 than in 1927.



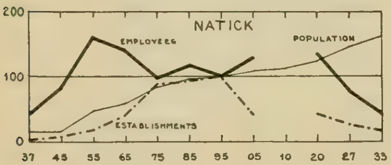
MILFORD. The number of industrial employees has been on the decline since 1855 and the number of establishments since 1875.



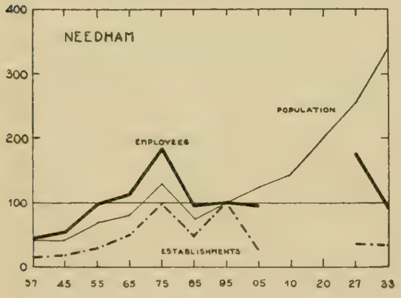
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100



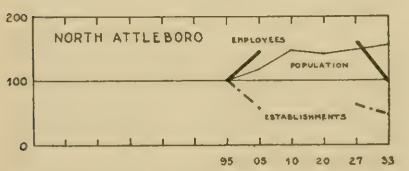
Milton. With rapidly increasing population, the number of establishments and employees has been on the decline until 1927. Since then there has been some increase in these items to the end of the period.



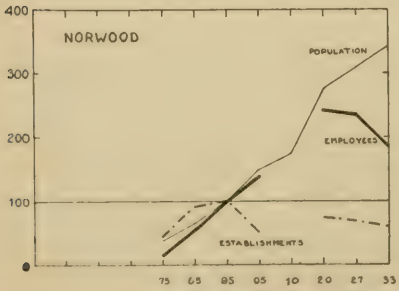
Natick. The population shows a gradual rise, but the number of employees has been declining since 1920.



Needham. Since 1885 the population has been rapidly increasing. The number of employees rose gradually until 1927, but declined into 1933.



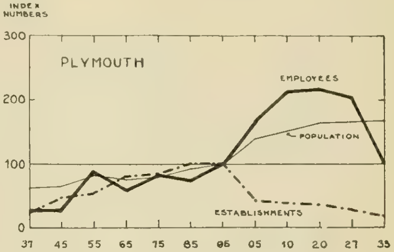
North Attleboro. Since 1895 when North Attleboro became an independent town, the population and number of employees have been on the increase, but the latter declined in the depression period.



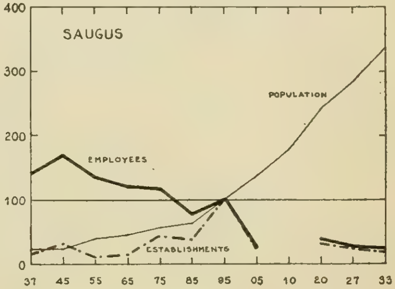
Norwood. Beginning with 1875 when statistics became available, both population and number of employees showed a very rapid rise. After reaching its peak in 1920 the number of employees shows a slight decline.

Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100

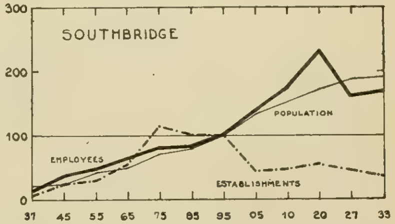
Plymouth. After 1895 the number of employees increased at a more rapid rate than did population. There has been, however, a considerable decline during the depression period.



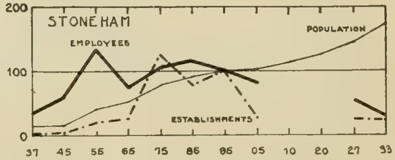
Saugus. Population has been rising at a rapid rate, while industrial employment and number of establishments were at their highest in 1895.



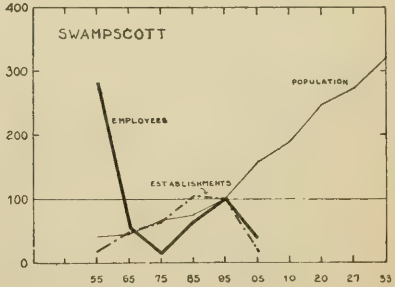
Southbridge. There has been a gradual increase in population and industrial employment, but the latter began a decline in 1920. In 1933 employment was slightly higher than in 1927.



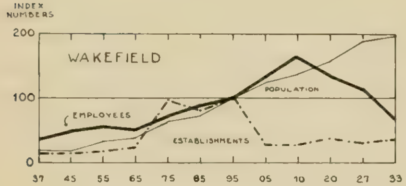
Stoneham. The number of employees reached its peak as early as 1855, although the population shows a gradual increase throughout the period.



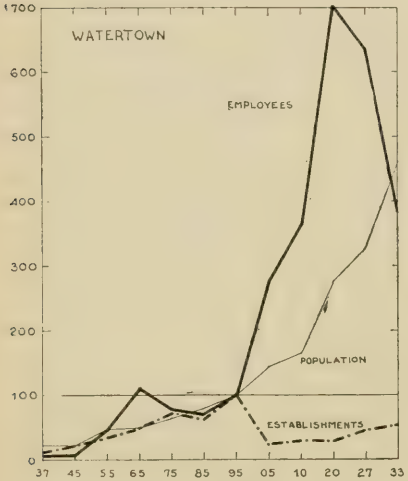
Swampscott. Population began a rapid increase in 1885, while the number of employees rapidly declined from its high peak in 1855 until 1875, and since then has been at a comparatively low level.



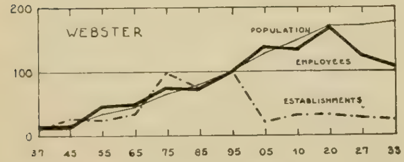
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100



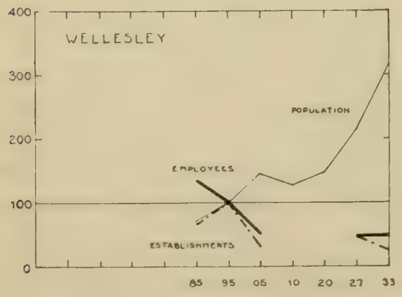
Wakefield. The peak in the number of employees was reached in 1910, while the population shows a consistent rise throughout the period.



Watertown. The number of employees increased at a rapid rate from 1895 until 1920, after which it declined.



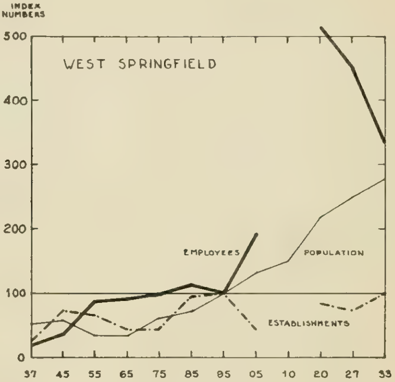
Webster. The number of employees and population increased at about an even rate until 1920. Since then the number of employees has declined.



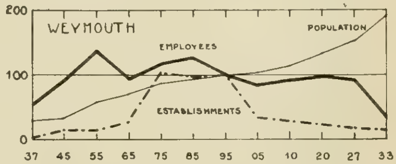
Wellesley. From the incomplete figures it appears that the population has been rising rapidly; but the number of employees reached its peak in 1885, declined until 1905, and has remained almost stationary since that time.

Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1933
1895 = 100

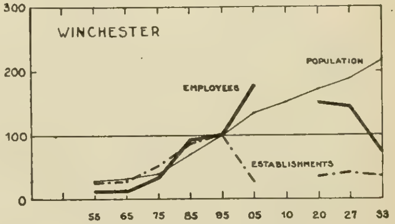
West Springfield. There was a consistent increase in population throughout the period. A very sharp rise in employment took place between 1895 and 1920, but data are lacking between 1905 and 1920.



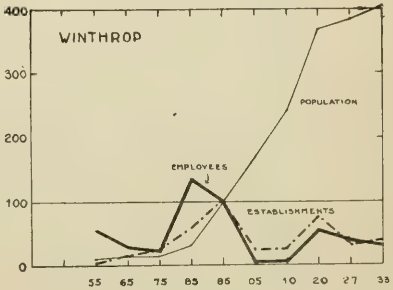
Weymouth. Up to 1895 both population and employment increased, but after that only population continued its upward trend.



Winchester. From the incomplete figures, it appears that population has been constantly on the increase, while the number of employees was at the highest in 1905. A considerable decline in the latter occurred during the depression period.



Winthrop. The number of employees reached its peak in 1885, while the population shows a very rapid rise through most of the period.

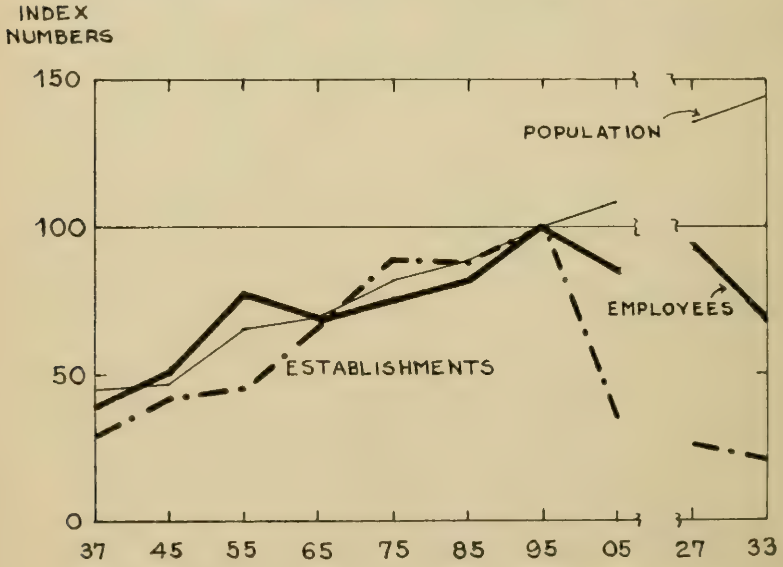


Sixty-nine Towns with Population Below 10,000

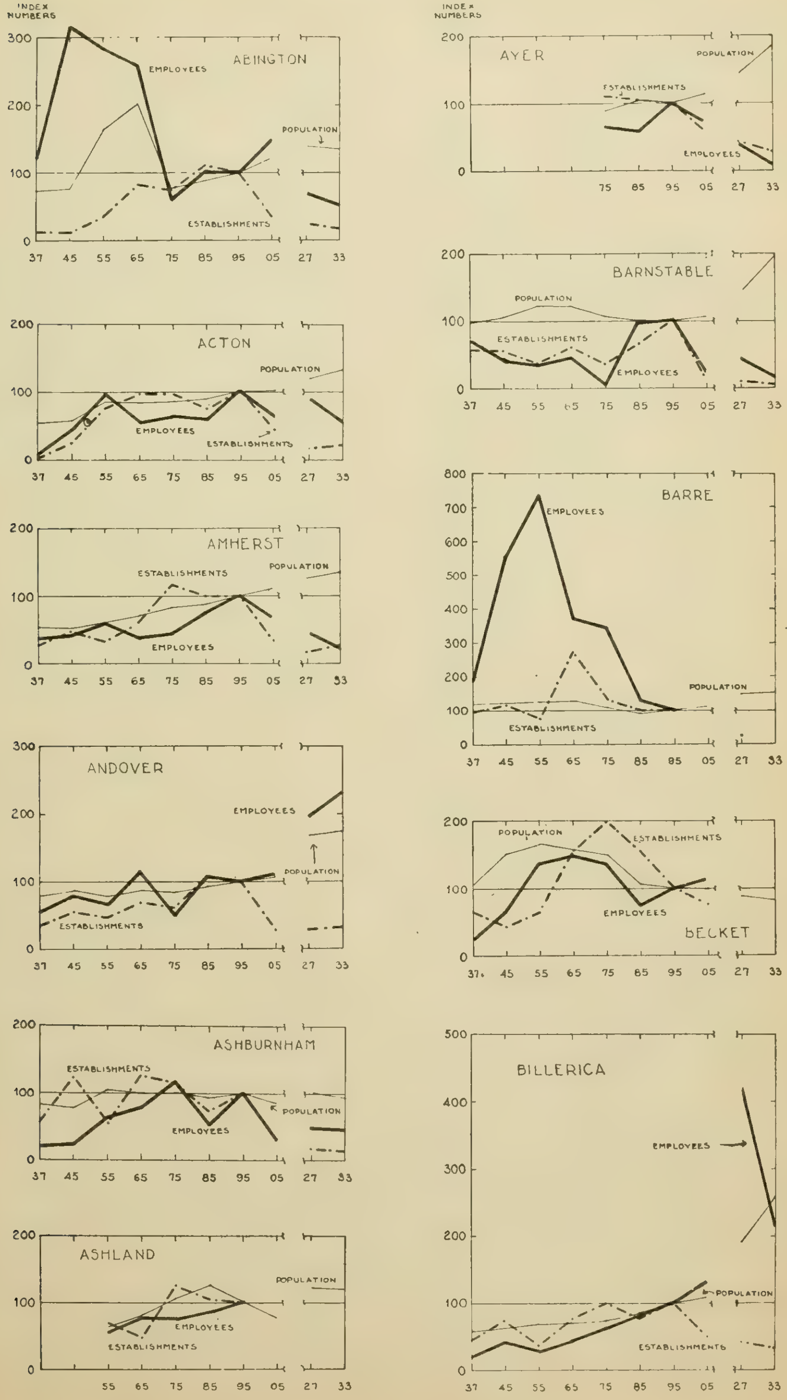
The index of population for 69 towns with population below 10,000 has been constantly rising through the entire period, being about 3 times as high in 1933 as in 1837. The number of industrial employees, while displaying an irregular movement, on the whole kept up with population growth until 1895. It declined in 1905 and then recovered in the period ending with 1927. A sharp decline registered in 1933 coincided with the low level of business activity in that year. The number of industrial establishments moved upward in accordance with the other two items until 1895, when a decline set in until the end of the period. As explained above, the sharp break in this index in 1905 is to be interpreted in the light of changes in the methods of statistical enumeration.

Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1927 or '33
1895 = 100

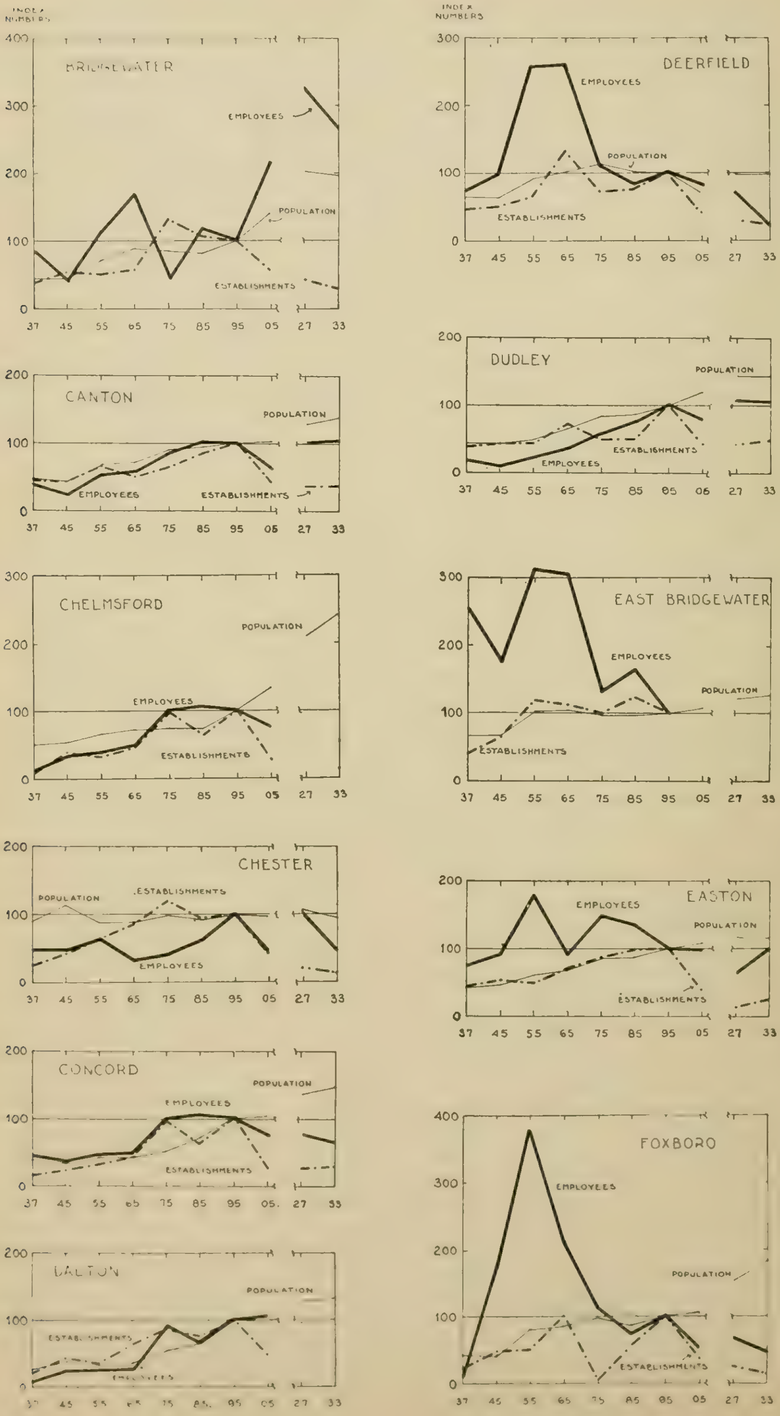
SIXTY-NINE TOWNS WITH POPULATION BELOW 10,000



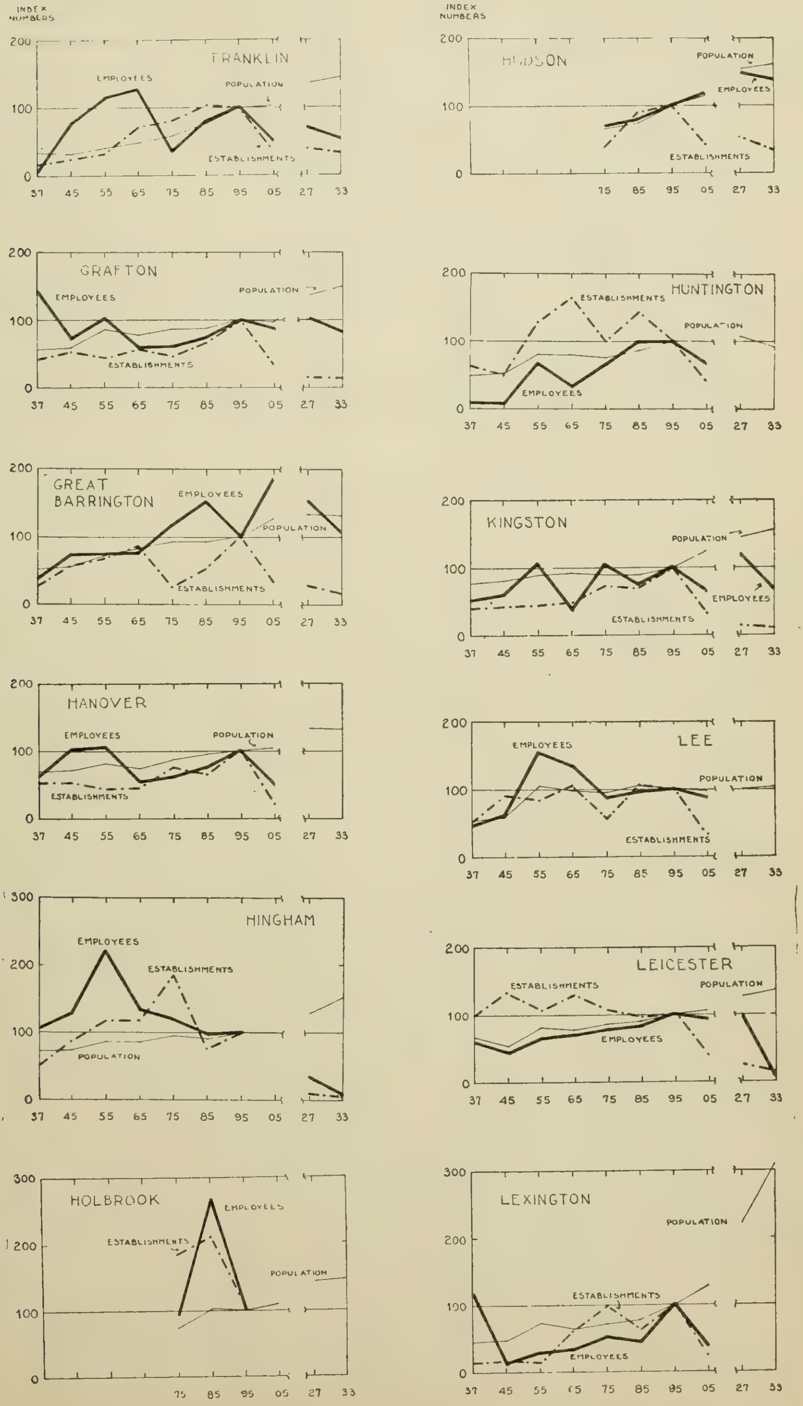
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1927 or '33
1895 = 100



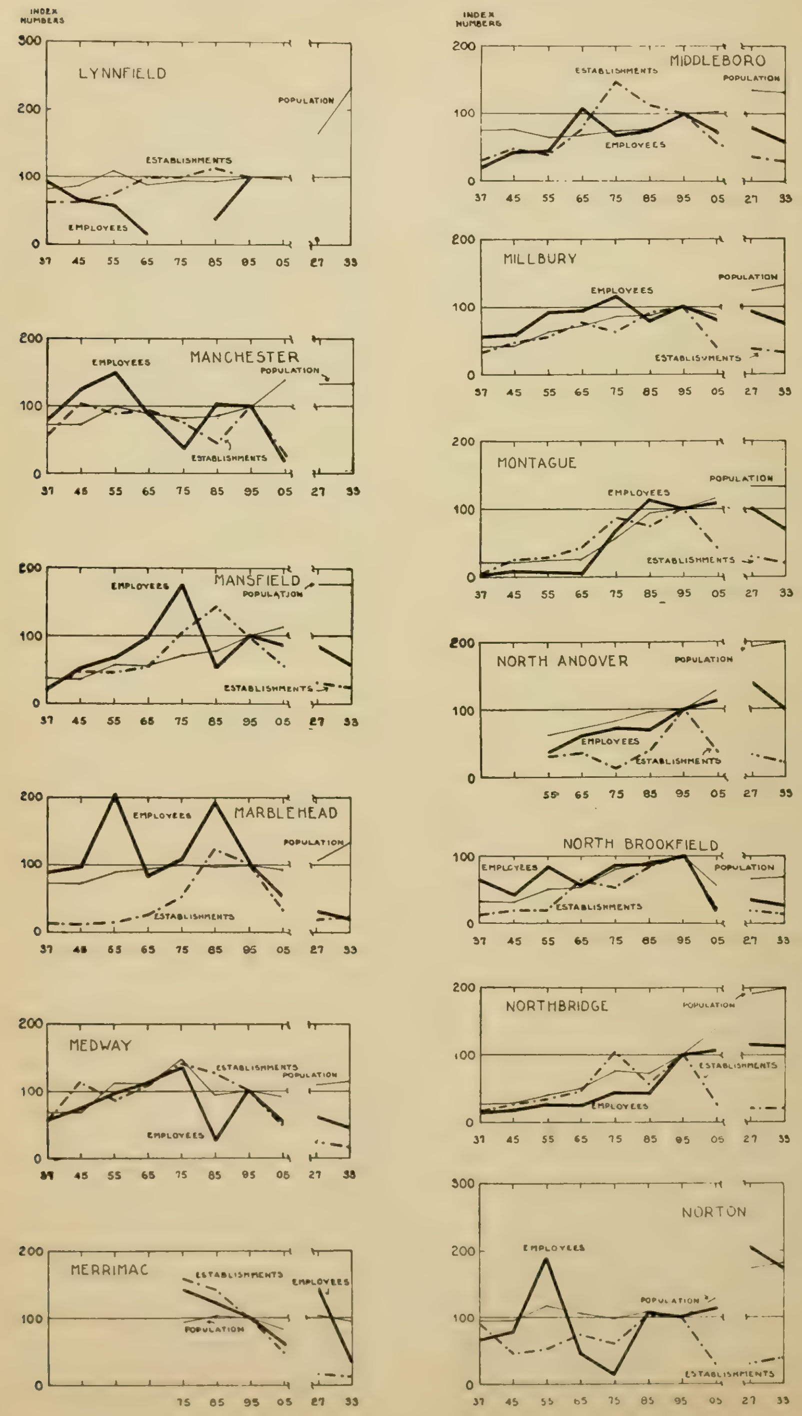
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1927 or '33
1895 = 100



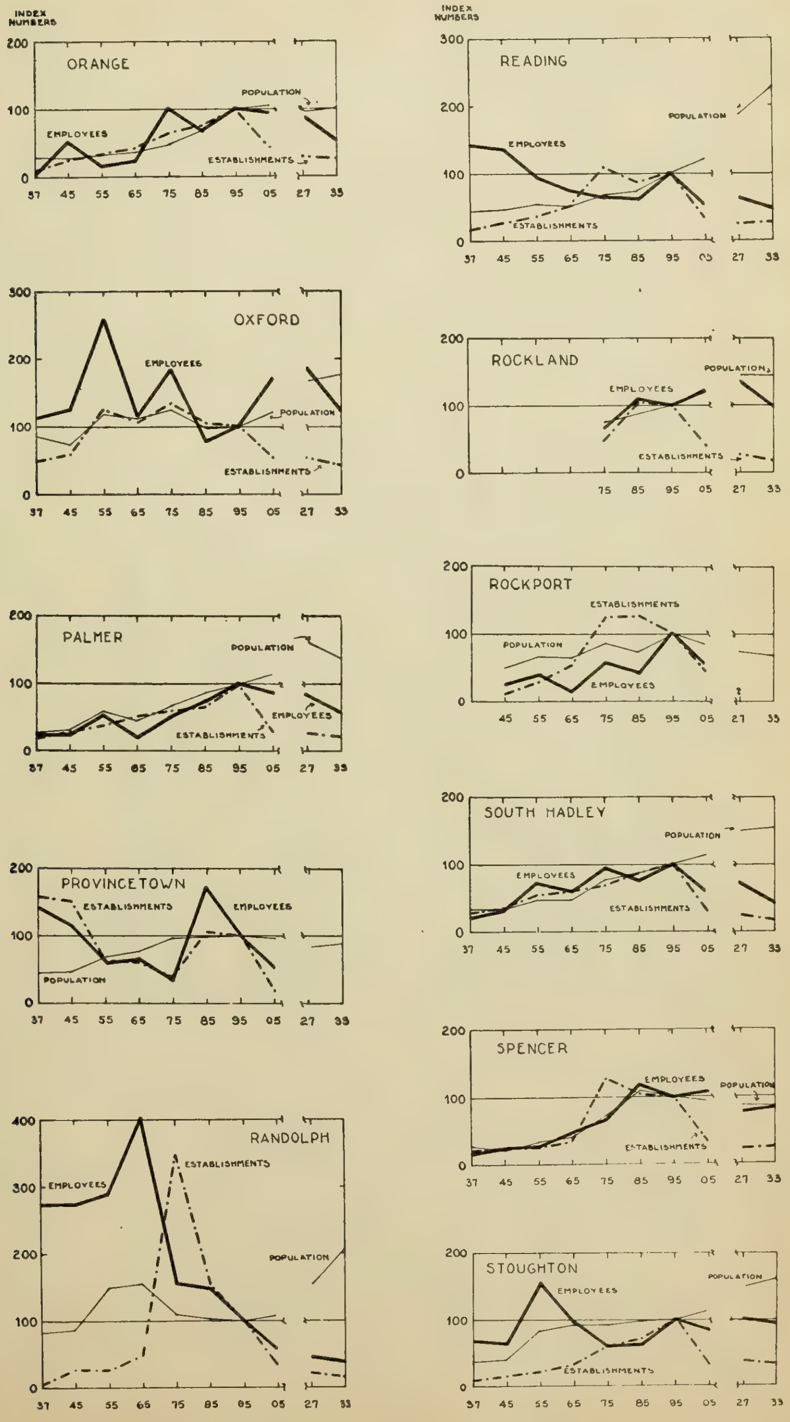
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1927 or '33
1895 = 100



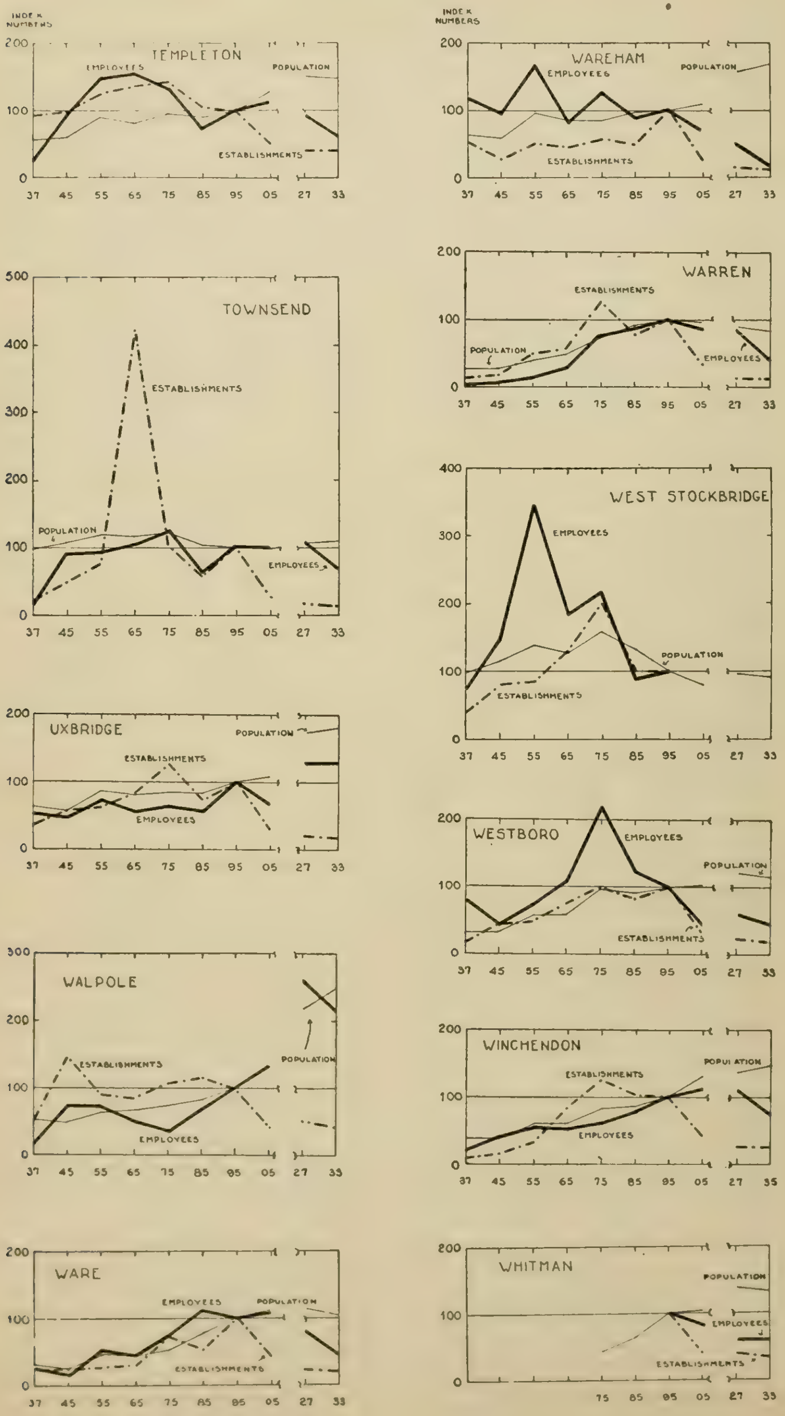
Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1927 or '33
1895 = 100



Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1927 or '33
1895 = 100



Trend in Population, Industrial Establishments, and Wage Earners, 1837 - 1927 or '33
1895 = 100

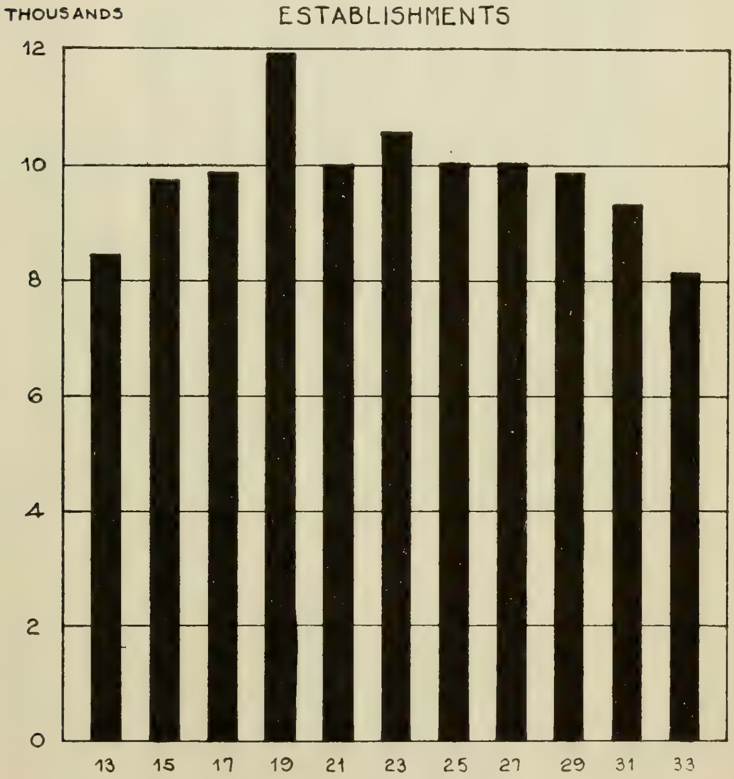


STATISTICS FOR INDUSTRIES

In the following charts a summary is presented covering the period from 1913 to 1933 indicating for all industries in Massachusetts the number of establishments, the wages paid during the year, the average number of wage-earners, the value of products, and the value added by manufacture.

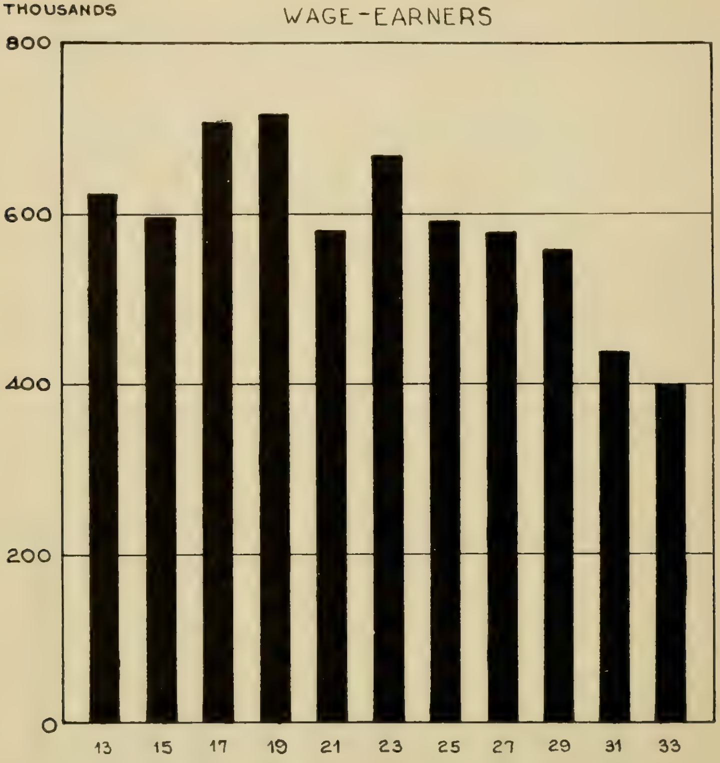
Principal Data for the Leading Manufacturing Industries of Massachusetts

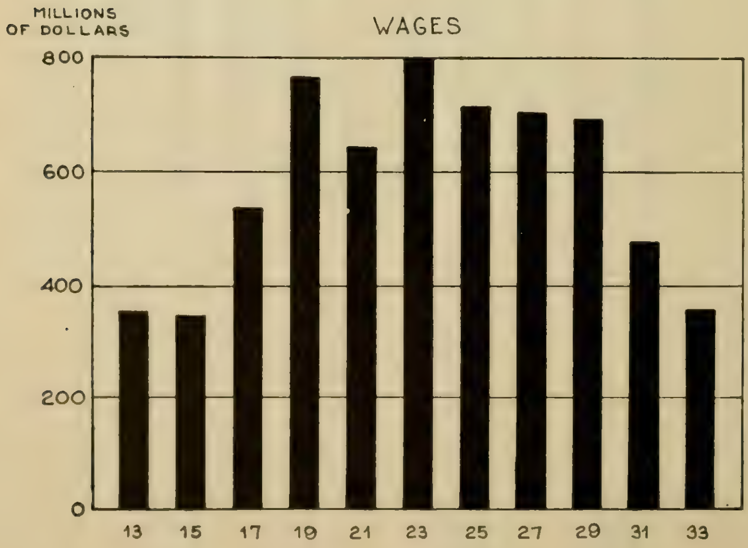
ALL INDUSTRIES, 1913 - 1933



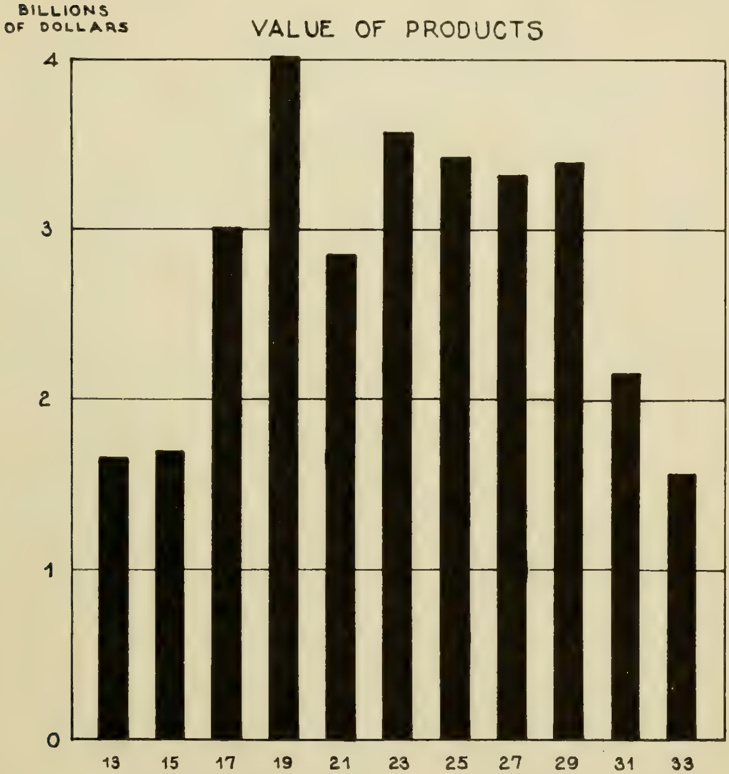
Principal Data for the Leading Manufacturing Industries of Massachusetts

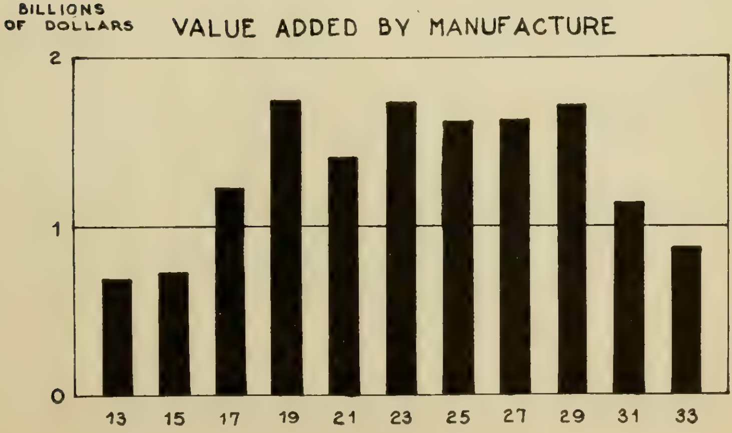
ALL INDUSTRIES, 1913 - 1933





Principal Data for the Leading Manufacturing Industries of Massachusetts
ALL INDUSTRIES, 1913 - 1933





VIRGINIA POLYTECHNIC INSTITUTE
AGRICULTURAL BRANCH LIBRARY
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 341 April, 1937

Vacuum-Pressure Relationships in Glass Canning Jars

By C. R. Fellers, A. S. Levine, and W. A. Maclinn

The present method of canning foods in the all-glass type of fruit jar has several disadvantages, some of which are overcome by a slight change in method of processing. Fundamental data are presented regarding the nature and development of internal pressures and vacuums in glass containers during thermal treatment.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

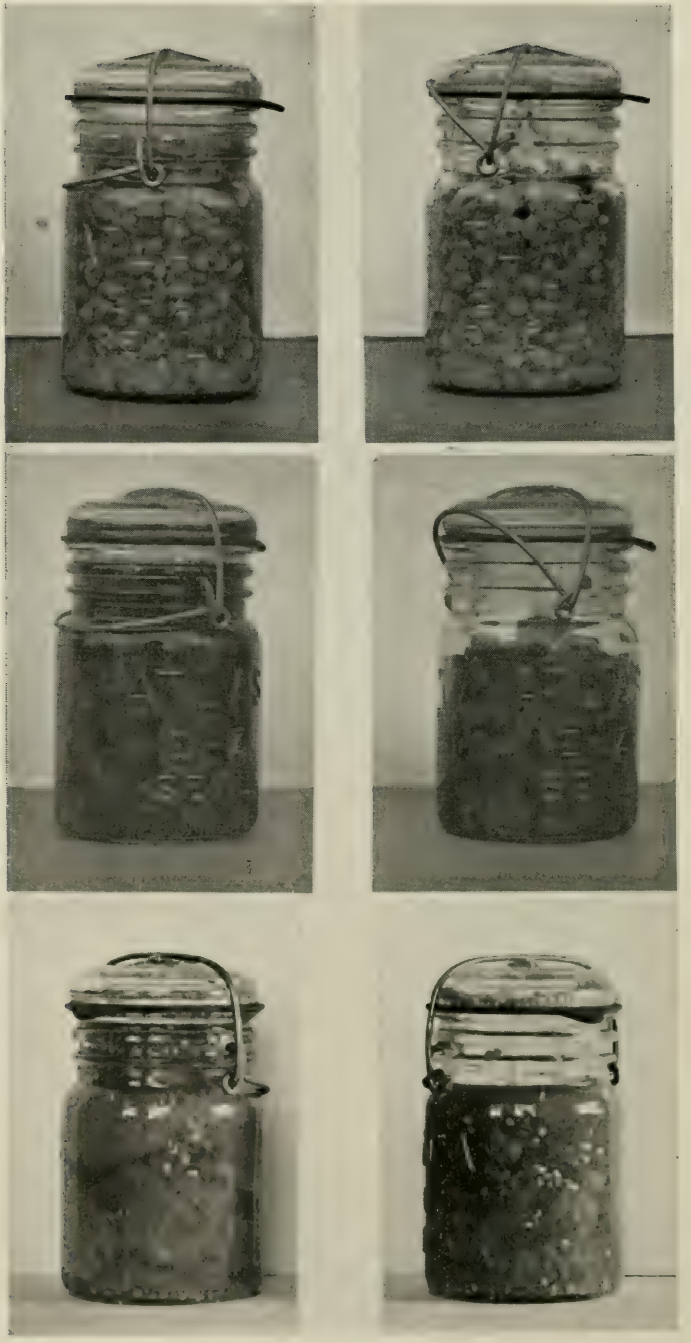


Plate I. Comparison of Liquid Levels in Jars Heat Processed when Partially and Fully Sealed.
Upper, Corn; Middle, Beets; Lower, Tomatoes.
(Note position of the wire bail in the partially sealed jars at the right; fully sealed jars at the left.)

VACUUM-PRESSURE RELATIONSHIPS IN GLASS CANNING JARS

By C. R. Fellers, Research Professor, A. S. Levine, Research Assistant and W. A. Maclinn, Instructor, in Horticultural Manufactures

INTRODUCTION

The all-glass container has several advantages over the commercial tin can which account for its extensive popularity among home canners and small-scale, quality producers. The glass container has a re-use value and attractive appearance, and does not require expensive sealing equipment.

The little previous original research on the subject of the glass container has received its stimulus from glass manufacturers and unorganized home canners. Ford (2, 3, 4) has studied extensively the processing of glass jars, but these studies were concerned with the metal closure types. Similar studies conducted largely on tin cans have been reported by Magoon and Culpepper (8, 9). The factors involved during processing (sterilizing) both in a water bath and under steam pressure seem to have been largely neglected. Maclinn (6) in 1933 started an investigation of this phase of canning and made a preliminary study of the Massachusetts method of processing the all-glass fruit jar. By this method the wire bail or clamp is placed in the tightened position prior to processing. This is commonly referred to as the "fully sealed" method.

The primary object of this paper is to present an account of the action of some physical factors involved, and incidentally to establish beyond all doubt the safety and efficiency of the "fully sealed" or Massachusetts method in the preservation of canned foods.

DESCRIPTION OF ALL-GLASS JARS AND HOW THEY ARE PROCESSED

The all-glass container consists of a glass jar and cover, a flexible rubber ring, and a wire bail which clamps the cover into the sealing position. The jar type commonly known as "E-Z Seal" was used in this investigation. When the wire bail is in place but not clamped tightly, the jar is said to be "partially sealed," as contrasted with the term "fully sealed," meaning that the bail is in the tightened position. (See Plate I.)

The common method of processing foods in all-glass containers is to submit the jar in a partially sealed condition to a boiling water bath or a steam pressure retort for a specified length of time. This heating destroys microorganisms and insures keeping quality of the product and safety to the consumer. In addition to destroying and inactivating microorganisms, the heat expands the enclosed gases, including water vapor, which create a pressure, lift the lid of the jar, and permit the gases to escape through the partially sealed closure. This release of expanded gases is called "venting." The wire bail is tightened and upon subsequent cooling of the jar a partial vacuum is formed.

THE PROBLEM

There is often a marked loss of liquid from jars processed in the customary partially sealed condition, referred to in this bulletin as "vent loss." This loss is much greater in steam-pressure processing than in water-bath processing. Fully sealing the jars prior to heat processing tends to alleviate this undesirable condition and eliminates the necessity of handling the hot wire bails and jars immediately after removal from the processing tank. (See Plate I.)

Although commonly called "fully sealed" when the bail is in the high tension position, this term is technically a misnomer because, when sufficient pressure is developed within the container, the glass cover will lift slightly permitting a release of the expanding gases and vapors as in the partially sealed condition.

LABORATORY EXPERIMENTS

VENT LOSSES DURING HEAT PROCESSING

The noticeable loss of liquid in partially sealed jars processed under steam pressure led to an investigation of vent losses occurring in jars partially and fully sealed, and with varying headspaces and processing periods.

The calculations of vent losses were made by weighing the jar, cover, rubber ring, wire bail, and water to the required headspace. After the heat processing period was over, the sealed jar was allowed to cool to 70° F. and then reweighed. The difference in weight was due to vent losses during the heat processing period. These data are expressed graphically in Figure 1.

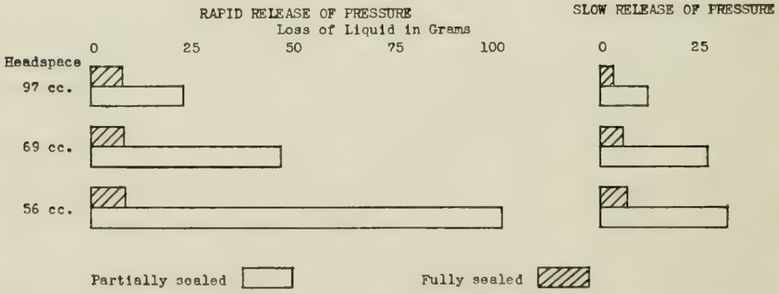


Figure 1. Average Vent Losses of Liquid in Partially and Fully Sealed Glass Jars Processed under Steam Pressure at 240° F.

In all of the 144 tests, the fully sealed jars had smaller vent losses than the corresponding partially sealed jars. The average loss of weight of 72 partially sealed jars was 44.6 grams; whereas, for the same number of fully sealed jars, the average loss was only 6.6 grams. The smaller loss of contents left the liquid level much higher in the fully sealed jars than in the partially sealed jars. This fact has a practical application in home canning, because loss of jar liquid results in an actual food loss as well as an unattractive appearance.

Furthermore, the possibility of later spoilage is increased, because as the liquid is forced out of the jar, it may carry with it particles of solid matter which get lodged between the rubber sealing ring and the lip of the jar, thus providing an entrance for spoilage organisms.

The pressure in the retort was reduced to zero rapidly and slowly to determine how this factor affected vent loss. The pressure was reduced to zero within one minute when released rapidly and within eight to ten minutes when released slowly. It is evident from a study of Figure 1 that a slow release of pressure from the cooker is the preferred method in order to avoid vent losses.

Relation of Headspace to Vent Loss

The results of the experiment show that the greater the original headspace in the jar, the less the vent loss during heat processing. In partially sealed jars with a headspace of 56 cc. the average vent loss was almost five times as great as in similar jars with a headspace of 97 cc., when the retort pressure was released rapidly; and almost three times as great when the retort pressure was released slowly. This same trend was noticeable in the fully sealed jars but to a lesser degree. The loss in the jars with the smaller headspace averaged two grams more than that in jars with the larger headspace. Fully sealed jars may, therefore, be filled to a higher level in packing than the partially sealed jars. However, it is not advisable to completely fill jars. A headspace of one-quarter inch is satisfactory for canning most food products.

Relation of Length of Processing to Vent Loss

The only significant difference between jar pressure and retort pressure occurs when the retort pressure is being released. The pressure within the jar lags behind the retort pressure until the difference becomes sufficient to raise the cover of the jar and release the pressure within, thus allowing the two pressures to come to equilibrium. This discharge of gases under pressure sometimes carries with it liquid from the jar, causing a vent loss, particularly when the jars are only partially sealed. As the greatest release of jar pressure occurs when the retort pressure is released, the duration of the processing after the maximum pressure in the jar is attained does not affect the vent loss. For example, a jar held at 240° F. for 30 minutes would have as much vent loss as one maintained for two hours at the same temperature. Observations on many jars show that the greatest losses of liquid occur in partially sealed jars at the time of pressure release.

Time of Venting of Fully and Partially Sealed Jars

A comparison of the time elapsing before venting takes place in the partially sealed and the fully sealed jars is indicated in Table 1. Of the 800 jars used, 400 were filled with water at 70° F. and 400 with water at 170° F., and all were immersed in a 180° F. water bath. In both cases, half the jars were partially sealed and half were fully sealed. Venting was readily discernible by means of the bubbles rising from the jars. As all the jars vented in the first eight minutes, and as the usual processing period in a boiling water bath is longer than ten minutes, jars processed with the bails tightened have as good a chance of venting as have jars processed partially sealed. This is further substantiated by the experimental evidence obtained in making a comparison of the vacuums formed in jars so processed.

TABLE 1. — TIME OF VENTING (PRESSURE RELEASE) OF FULLY AND PARTIALLY SEALED JARS FILLED WITH WATER AND PROCESSED IN A WATER BATH AT 180° F.

Time of Venting	Filling Temperature 70° F.		Filling Temperature 170° F.	
	Fully sealed jars	Partially sealed jars	Fully sealed jars	Partially sealed jars
Minutes	*Number*	*Number*	*Number*	*Number*
1	92	200	69	200
2	64	0	67	0
3	10	0	16	0
4	18	0	22	0
5	10	0	12	0
6	2	0	4	0
7	4	0	6	0
8	0	0	4	0
Total	200	200	200	200

PRESSURES DEVELOPED IN GLASS JARS DURING THERMAL TREATMENT

Method of Determining Pressure

A consideration of the safety of the fully sealed method entails a study of the internal pressures developed in glass jars during processing. To insure safety to the manipulator, the glass jar must be able to withstand the highest pressure that may develop within it.

In order to study the internal pressures developed during processing in a boiling water bath and in a steam pressure retort, it was necessary to connect the inside of a jar with an open U-tube manometer containing mercury. Holes drilled in glass covers caused these covers to crack as soon as they were placed in hot water. The best means was found to be the use of an aluminum cover duplicating exactly the measurements of an ordinary glass cover. Aluminum was chosen as the metal because of its rust resistance and light weight. A one-eighth inch brass tube, 2.5 inches long, was threaded into a hole in this aluminum cap and was connected to the U-tube manometer by means of 8 mm. pressure tubing. (Plate II shows this pressure determination apparatus.) For steam pressure retort determinations the safety valve in the cover of the retort was removed and the pressure tubing attached to a brass tube inserted in the hole. All connections were sealed with a mixture of litharge, glycerin, and cement. The volume of the tubing was 123 cc. and, being a constant, was not added to the varying headspaces used. Headspaces include that space under the cover when the cover is on the jar.

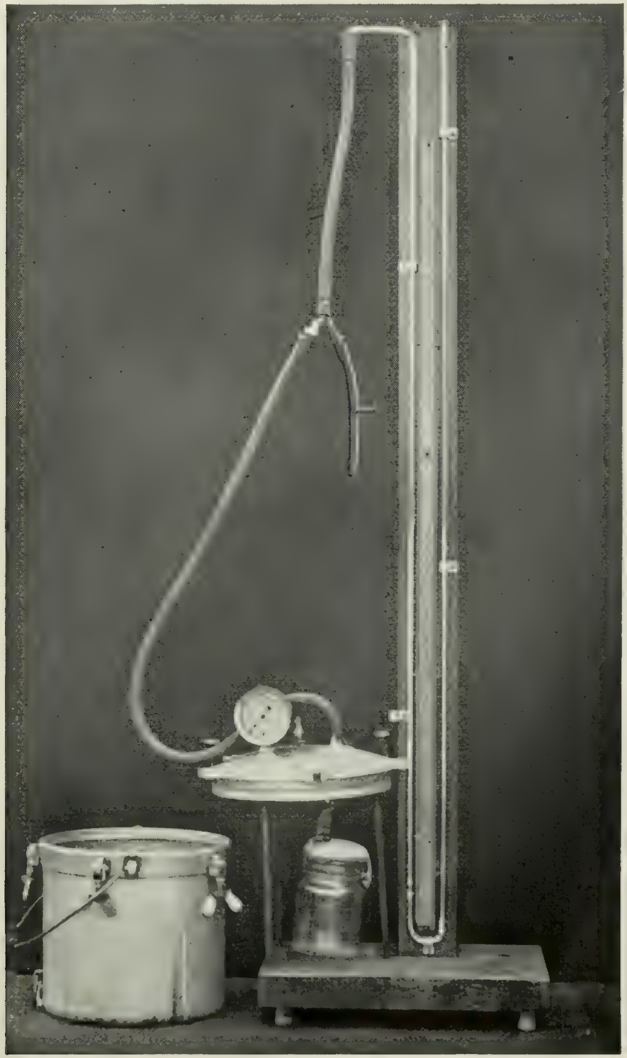


Plate II. Apparatus for the Determination of Internal Pressures.

Effect of Temperature Alone on Internal Pressure

In order to study separately the physical factors involved during the processing of glass jars, it was necessary to utilize some means whereby only one factor at a time caused any change. Temperature and pressure are the two main physical factors. To study retort temperatures without the influence of external pressure, an oil bath was used because oil would reach a temperature equal to that attained in a retort having 10 pounds steam pressure, namely 240° F. Venting points in experimental jars immersed in the oil bath were readily recognized by one to two millimeter fluctuations in the mercury column.

Figure 2 shows graphically the development of pressures and resultant venting in partially and fully sealed jars filled with water and heated in an oil bath. The data show that the partially and fully sealed jars vented at pressures of 0.1 and 1.8 pounds per square inch, respectively.

The elapsed time before venting occurred was not so important as the pressures at which venting occurred because in heating the oil, care had to be taken to prevent violent agitation. The electric heating unit used to regulate the heat was not subject to fine adjustments.

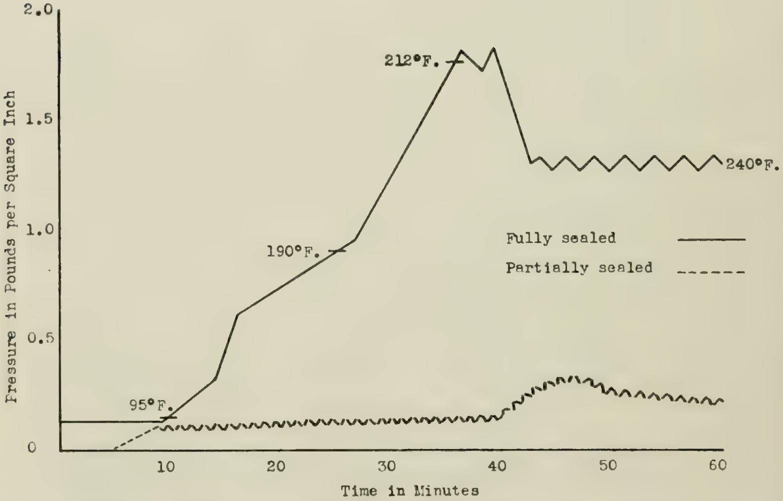


Figure 2. Pressure Developed in Partially and Fully Sealed Glass Jars Processed in an Oil Bath through the Temperature Range of 75° to 240° F. (Headspace 75 cc.)

Effect of Pressure Alone on Internal Pressure

In order to study retort pressure effects without the influence of heat, an air pressure pump was attached to the petcock of a small pressure cooker. The experimental jar with a tube leading from the cover of the cooker to the U-tube manometer was placed inside of the retort and the cover clamped down tightly. The jar contained water at 70° F. and had a one-half-inch headspace. The pump was started and air flowed into the retort. Seven pounds was the maximum pressure obtainable in the cooker as indicated on its gauge. Jar pressure readings were made as usual on the mercury column of the manometer. Pressures obtained in three partially sealed jars were 0.68, 6.77, and 6.50 pounds per square inch, respectively and for three corresponding fully sealed jars: 0.1, 0, and 0 pounds per square inch.

There was a slight water loss in the partially sealed jars but none in the fully sealed jars. The low rise in pressure in the first partially sealed jar is thought to be due to the rapid increase of retort pressure which made its way into the partially sealed jar only to the extent of 0.68 pounds per square inch before the excessive retort pressure completed the seal. On the duplicate trials with the partially sealed jars, pressure was drawn into the retort more slowly, with the result that there was a corresponding rise in jar pressure and retort pressure. On duplicate trials with fully sealed jars there was no rise in jar pressure — a further indication that the system did not leak.

Internal Pressures Developed in Water-Bath Processing

Partially sealed jars of water processed in a water bath did not build up any appreciable pressure. The mean for eight jars was approximately 0.1 pound per square inch. The fully sealed jars, however, showed a maximum pressure of 6.19 pounds per square inch after heating slowly for 55 minutes in a water bath through the temperature range of 70° to 212° F. In the eight jars, the pressure range at time of venting was 2.42 to 6.19, with a mean of 4.82 pounds per square inch. In the partially sealed jars the venting occurred in from 6 to 10 minutes, with an average of 7 minutes; for the fully sealed jars the range was 21 to 55 minutes, with an average of 37 minutes. These data may appear misleading in indicating that the venting of fully sealed jars does not occur until after a long heating period. This was not the case as observed in actual practice where the jars were placed in fairly hot water. Actually, venting occurred within a few minutes, as shown in Table 1. Repeated observations were made on jars of raspberries, blueberries, tomatoes, and other small fruits that were fully sealed before processing in a water bath. They invariably vented in 1 to 3 minutes. Jars showing no vacuum, thereby indicating no venting, have not been found, whether water-bath or pressure processed. This shows that venting always occurs even when the jars are fully sealed. Figures 3 and 4 show typical curves for jars processed in a water bath.

Although the experimental jar apparatus was used to secure the results shown in Figure 4, the curves demonstrate more clearly the slight margin of difference in results obtained with the two methods of sealing. When fully sealed jars were placed in a water bath at 190° F. and heated to 212° F., venting occurred at from 2.7 to 3.3 pounds per square inch in from 5 to 9 minutes. As the venting is the main cause of the vacuum, if both fully and partially sealed pint jars with the same headspace vent at about the same time and to the same degree, they will both have the same amount of vacuum when the jars are cooled after processing.

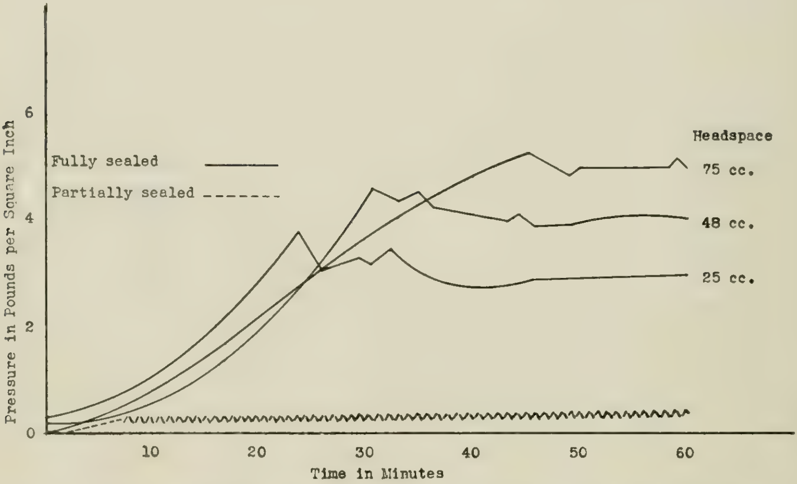


Figure 3. Pressure Developed in Partially and Fully Sealed Glass Jars Processed in a Water Bath through the Temperature Range of 70° to 212° F.

The maximum pressure measured in a glass jar during processing in a water bath was 6.86 pounds per square inch. Differences in time of venting and pressures of duplicate jars are most likely due to differences of bail tensions and variations in covers and rubber cover seats. Although the pressure developed in fully sealed jars processed in a water bath is from two to six pounds higher than that developed in partially sealed jars, there has been no experimental or practical evidence yet produced to show that this pressure is in any way dangerous or likely to cause an explosion of the jar. As an added precaution in the use of the Massachusetts method in pressure processing, however, it is advisable to release the pressure in the cooker as slowly as possible. By the time the jar is cool enough to remove from the cooker, the internal pressure has been diminished to such an extent that it is not sufficient to cause any damage even if the jar should crack because of a flaw.

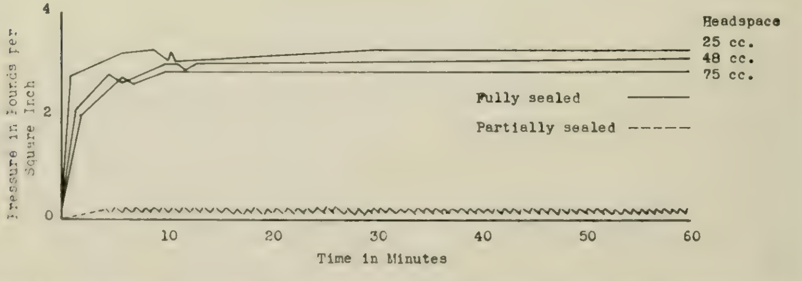


Figure 4. Pressure Developed in Partially and Fully Sealed Glass Jars Processed in a Water Bath through the Temperature Range of 190° to 212° F.

Although from Figures 3 and 4 one might conclude that a fully sealed jar vents only once or twice during the whole processing period, this is not the case, for in water-bath processing one can see the continually escaping gas bubbles once the jar vents. This venting continues steadily until the processing period is completed. Headspace is also of little consequence in fully sealed jars. The amount of pressure developed depends more on the condition of the rubber ring, the tension of the bail, and the fit of the cover. An increase in the filling temperature and in the initial temperature of the water bath serves only to cause a more rapid rise of internal pressure, as shown in Figure 4.

Internal Pressures Developed in Pressure-Cooker Processing

While the fully sealed method was found desirable to use in water-bath processing, the advantages of the method were still more noticeable in pressure processing. It is in the latter method of heat preservation that the largest losses of liquid are encountered. Representative data are presented in Figure 5. If a jar is partially sealed, placed in a pressure cooker, and processed at a steam pressure of 10 pounds per square inch, the pressure within the jar will also be 10 pounds. When the pressure is released from the pressure cooker, the excess jar pressure will also be released at the same rate. Thus, liquids and vapors are lost to such an extent that there is a noticeable loss in volume of contents of the cooled jar. Although a fully sealed jar, heat processed under similar conditions, will also develop an internal pressure of approximately 10 pounds per square inch, it will release this pressure so slowly, upon release of the cooker pressure, that there will be practically no loss of liquid from the jar contents. It was to prevent the loss of jar contents and to improve the appearance of the finished product that the fully sealed method was originally tried for pressure processing. Yet, with the improved appearance there is no sacrifice of keeping quality. The internal changes occurring during the heat processing are practically the same in both methods. This is clearly shown in Figure 5. When the jars were filled cold and heated in a pressure cooker at 240° F., curves similar to Figure 5 were obtained.

Ordinarily, pressures in partially sealed jars rise and fall with the cooker pressure, but occasionally they may lag behind the cooker pressure because of a faulty cover seal which causes the jar to act like a fully sealed jar. Also, from the data one can see that after the petcock of the cooker was closed, each jar apparently vented only once or twice. This was due to fluctuations of cooker pressure beyond the control of the operator. A decrease or an increase of as little as 0.25 pound per square inch in the cooker made a noticeable corresponding change in the jar pressure. Theoretically, if a cooker pressure does not fluctuate but rises constantly to the desired point and remains there, the fully or partially sealed jar will not vent until the cooker pressure is released. However, this is improbable in actual practice, for even automatically controlled pressure cookers shut off at regular intervals during the processing period long enough for venting to take place.

Fully sealed jars are slightly slower in attaining retort pressure than partially sealed jars, but also release their pressures more slowly in cooling, thus equalizing the time held at a definite pressure.

Differences in headspace and in filling temperatures make little difference in the pressure developed. The extent of pressure created in the jars is entirely dependent on the pressure developed in the pressure cooker, regardless of the type of seal.

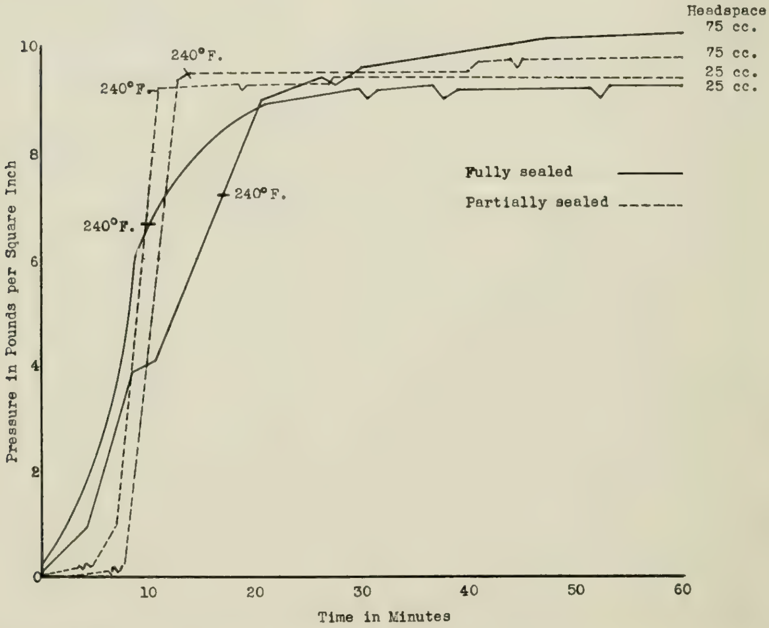
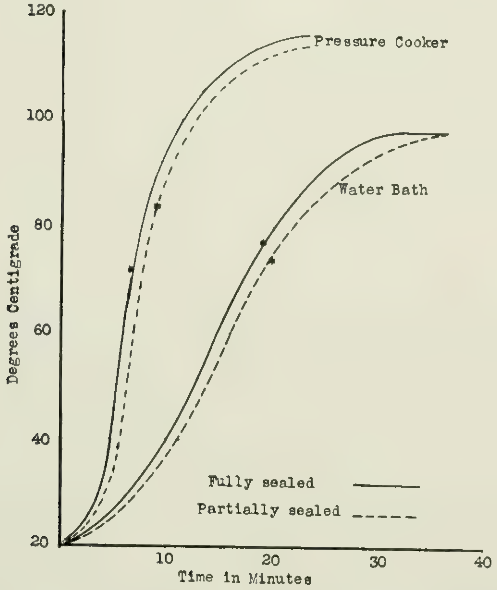


Figure 5. Pressure Developed in Partially and Fully Sealed Glass Jars Processed in a Pressure Cooker at 240° F. Filling temperature 180° F.

HEAT PENETRATION STUDIES ON PARTIALLY AND FULLY SEALED GLASS JARS

The object of subjecting foods to heat, as previously stated, is to prevent spoilage and to destroy pathogenic microorganisms. The processing time is that which accomplishes the primary object of sterilization but does not seriously impair the plant or animal tissue. Theoretically, the rate of heat penetration should not be affected by fully sealing a jar during processing.

In order to determine whether any differences exist in the transfer of heat to partially sealed and to fully sealed jars, a series of experiments was conducted using a standardized thermocouple and a Leeds and Northrup Potentiometer Indicator to determine the millivolts indicative of temperature. The results are presented in Figure 6, and show quite clearly that there were no marked differences in the penetration of heat in partially sealed and in fully sealed glass jars of water processed either in a water bath at 212° F. or in a pressure cooker at 240° F.



*Water bath boiled (212° F.). Steam pressure reached 10 pounds.

Figure 6. Heat Penetration in Partially and Fulled Sealed Glass Jars Processed in a Water Bath and in a Pressure Cooker.

VACUUM

A good partial vacuum in the sealed jar is of primary importance in the canning of food. Vacuum is generally expressed in "inches of mercury" and may be described as the absence of "normal pressure." Normal or atmospheric pressure is that pressure due to the weight of the air enveloping the earth, and at sea level is approximately 15 pounds per square inch.

If a jar is closed at room temperature, the air within exerts the same pressure outwards as the atmosphere without exerts on the container. If a part of the air in the jar is removed and the jar is then closed, the remaining air exerts less pressure outwards than the atmosphere exerts upon the outside of the jar, and it is said that a "partial vacuum exists in the container." Atmospheric pressure at sea level is sufficient to support a column of mercury 29.92 inches high, having a cross-section of one square inch. If the air remaining in the "partial vacuum" supports a column of mercury to a height of 20 inches, then the difference between the heights of the two columns, 10 inches, represents the "vacuum." This vacuum is what is meant whenever the word is used in general literature on canned food.

A vacuum is produced in the all-glass jar either by heating the food before it is packed or by heating the product in the container. The application of heat causes the internal gases and vapors to expand and escape by means of the jar "venting." Upon cooling there is a contraction of the expanded gases, vapors, and solids and a partial vacuum is formed within the container. Thus, the formation of a vacuum depends mainly on the venting of the jar. In addition to inhibiting the growth of spoilage microorganisms, the vacuum serves to maintain an effective seal. The function of the wire bail is mainly to direct the glass cover down in close contact with the rubber ring to a correct setting while the vacuum is forming.

Obviously, the normal method of determining vacuums by piercing the cover with a pointed gauge, graduated for the purpose, cannot be carried out on glass-covered jars. Consequently, two methods were used for determining vacuums in glass-covered jars (7).

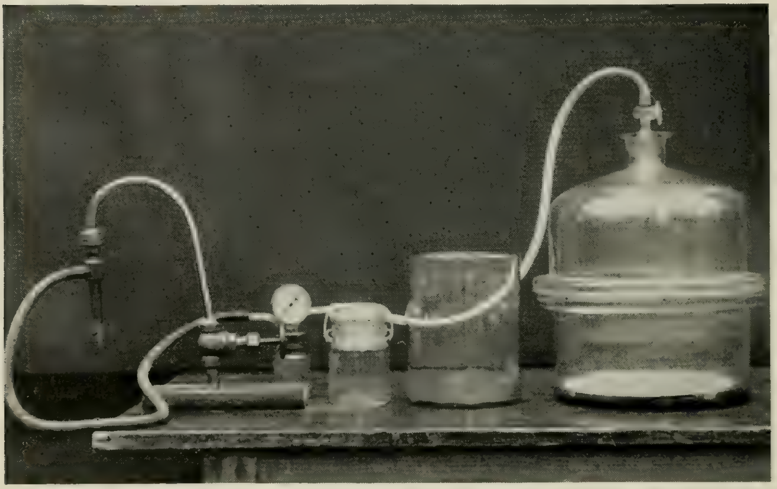


Plate III. Apparatus for the Determination of Vacuums by the Vacuum Desiccator Method.

Methods of Determining Vacuum

Vacuum Desiccator Method. — In this method a desiccator is connected to a water pump by means of vacuum tubing. (See Plate III.). The connections are made tight so that a vacuum of 27 or 28 inches can be obtained. After loosening the bail, the jar is immersed in a large glass jar of water, which is then placed in the desiccator and the aspirator allowed to slowly exhaust the air from the system. When the vacuum inside the desiccator becomes higher than that in the jar of food, the glass cover will lift, breaking the vacuum and allowing bubbles to escape from the jar. The vacuum gauge, which is set between the faucet and the desiccator, is read at this time. The vacuum present in the jar of food is slightly lower than the reading on the vacuum gauge. The slight resistance of adhesion between rubber rings and jar is negligible in most cases of freshly sealed jars. In this work most jars were examined within a day after canning.

Water Displacement Method. — The second method eliminates the error of adhesion between rubber ring and cover.

The jar with its contents is weighed after processing, then immersed in water in an inverted position and the seal broken, permitting the headspace to fill with water in proportion to the vacuum in the headspace. With the jar still inverted, the water levels inside and outside the jar are made the same, the cap is replaced, the clamp tightened down, and the jar is then removed from the water, wiped off, and reweighed. The difference in weight between the second and first weighings gives the amount of water which was sucked in. The lid is then removed and the jar filled completely with water, including the space under the glass cover, after which it is weighed again. This weight minus the first weight gives the volume of headspace. The vacuum can be determined from the weight of the water sucked in and the volume of the headspace, as shown in the following example:

a. Weight of jar and contents after processing	980 grams
b. Weight after opening under water	1,030 grams
c. Gain in weight (b–a)	50 grams (cc.)
d. Weight of jar completely full	1,050 grams
e. Original headspace volume (d–a)	70 grams (cc.)
f. Vacuum $\frac{b-a}{d-a}$ x 30	21.4 inches

Effect of Type of Seal on Vacuum Formation

Table 2 shows the results of vacuum determinations made on fully sealed and on partially sealed jars filled with water at 70° F. and processed in a boiling water bath for 5, 10, 15, and 20 minutes. There was little difference in the vacuums formed in jars processed fully sealed and partially sealed for the same length of time. Because of inherent differences in methods of canning in glass and tin containers, the former usually have a higher vacuum after thermal treatment. This is because the tin can is completely sealed and the glass jar incompletely sealed during thermal treatment.

A vacuum of 20 inches or more is so well above the safety line that a difference of one or two inches due to the condition of the seal at the time of processing is not going to affect the keeping quality of the contents of the jar. The average vacuum considered safe for preserved foods in tin cans is 12 inches according to Clark, Clough, and Shostrom (1).

The data in Table 2 were secured also to check the efficiency of the two methods of determining vacuum in all-glass jars. The two methods were found to be in satisfactory agreement in their results.

In order to discover the effect of the type of seal during pressure processing on subsequent vacuum formation, a series of pint jars was processed 5, 10, 15, and 20 minutes in a pressure cooker at 10 pounds steam pressure. Duplicate jars were partially and fully sealed. On one set of jars the pressure was released slowly from the retort; on the other set the pressure was released rapidly. The results showed that the vacuums formed in jars processed in pressure cookers were practically the same regardless of type of seal when processed and regardless of pressure release conditions, e.g., rapidly or slowly. For example, the average vacuum attained in 16 fully sealed jars was 25.6 inches and in the partially sealed jars, 27.6 inches when the pressure in the cooker was released rapidly; when the pressure was released slowly, the average vacuums were 24.1 and 28 inches, respectively. Normal variations in headspace and variations in filling temperatures ranging from 70° to 212° F. had no effect on resulting vacuums. The vacuum range was 19.2 to 26.7 inches in 72 glass jars heat processed for 20 minutes in a water bath with the headspace of 65 to 72 cc. and filling temperatures of from 70° to 210° F. More detailed and extensive data on the subject of vacuum–pressure relationships in glass jars during processing are given in the theses of Maclinn (6) and Levine (5).

TABLE 2. — EFFECT OF TYPE OF SEAL ON VACUUM AS DETERMINED BY THE VACUUM DESICCATOR AND THE WATER DISPLACEMENT METHODS

Processing time	Vacuum Desiccator Method				Water Displacement Method			
	Vacuum in fully sealed jars		Vacuum in partially sealed jars		Vacuum in fully sealed jars		Vacuum in partially sealed jars	
Minutes	*Inches of Hg*		*Inches of Hg*		*Inches of Hg*		*Inches of Hg*	
	Jar 1	*Jar 2*	*Jar 1*	*Jar 2*	*Jar 1*	*Jar 2*	*Jar 1*	*Jar 2*
5	14	14.7	17	4	13.9	14.7	17.2	....
10	17.7	17.2	....	24.8	17.1	18.9	18	18.2
15	20	18.2	25.5	27.5	17.1	18.3	23.2	19
20	21	....	25	26.75	24.1	4.2	26.5	26
5	13	12.4	17.5	....	16.5	17.1	18	17.2
10	17.1	17.9	23.5	24.5	18.9	17.4	19.25	23
15	17.9	17.8	25.25	25	15.9	17.1	25.6	24.5
20	18.8	19.4	26	27.1	14.4	20.4	27	27
5	15	15	16.8	17.25	18.9	....	16.5	18
10	16.9	18.1	25	25	17.4	16.8	19.75	22
15	19.7	20.1	26.5	24.8	18.6	20.4	24.9	26.5
20	19.6	19	26.5	26.5	17.1	18	27.25	26.5

COOPERATIVE CANNING EXPERIMENTS WITH HOME CANNERS

During July and August of 1935 some 5,586 all-glass jars were distributed to experienced home canners of western Massachusetts with the stipulation that all processing of these jars be done with the bail tightened, i.e., fully sealed. Each cooperator was also provided with new rubber rings, a set of instructions and precautions, a book of canning recipes, and a form sheet to be returned to the laboratory. The form sheet was to contain data on loss of liquid and breakage during processing. In addition to the new jars distributed, almost 12,000 old jars were used in the canning experiment.

The data obtained from these cooperators were tabulated and are presented in Tables 3 and 4. Several hundred of these jars were examined by the authors.

TABLE 3. — RESULTS OF REPORTS FROM HOME CANNERS USING THE FULLY SEALED METHOD OF CANNING.

Number of cooperators		64	
Number of reports received		56 or	87 percent
Number of jars	Issued	Reported	
Pints	2,772	2,338	
Quarts	2,640	2,148	
Half gallons	174	174	
Totals	5,586	4,660 or	84 percent
Additional jars reported			
Quarts		2,404	
Half gallons		9,524	
Total		11,928	
Total jars reported		16,588	
Breakage — Jars			135 or 0.81 percent
Covers			55 or 0.33 percent
Total			190 or 1.14 percent

Method of processing	Number of jars	Breakage
Steam pressure — 10 pounds, 240° F	2,287	21 or 0.91 percent
Water bath — 212° F	14,287	169 or 1.18 percent
Electric oven — 275° F.	14	0
Totals	16,588	190

Loss of liquid	None	Slight	Moderate	Marked
Pints	1,901	494	169	82
Quarts	2,696	1,176	172	22
Half gallons	9,597	61	28	0
Totals	14,194	1,731	369	104
Percent	85.5	10.4	2.2	.62

There was no serious breakage nor loss of liquid in any one case. The most dangerous breakage reported was that of a jar which "cracked with some violence." Usually cracked jars can be lifted out of the retort or water bath in one piece. One cooperator inadvertently permitted the pressure in the cooker to rise to 30 pounds. Upon opening the cooker she found that there was neither breakage nor loss of liquid in the jars of that batch. It is interesting to note that the percentage of breakage in water-bath processing and in pressure-cooker processing is about the same, viz., 1 percent.

Although cautioned not to fully seal glass jars in oven canning, one cooperator did process 14 quarts of tomatoes for 90 minutes at 275° F. in an electric oven. Although no difficulties were encountered in this instance, it is still deemed inadvisable to use oven canning, particularly for fully sealed jars.

Meat products and corn caused the most difficulty in canning, both in the laboratory and afield. It was in the canning of these products that reports showed that several jar rubbers were pushed out beyond the point of effective sealing. This was true mainly in the case of meat where the fat tends to grease the rubber ring and permits the internal pressure to push it out easily, causing a "blown" condition and a faulty seal. Partial sealing does not prevent this undesirable condition. A very large headspace, approximately one or two inches, lessens the extent of lubrication by the fat and largely prevents the blowing of rubber rings. In several instances jars of corn showed marked loss of liquid. However, in the laboratory canning of corn care was taken to keep the sealing rim of the jar free of corn particles and good results were obtained.

Of the 16,588 jars processed fully sealed, cooperators reported no noticeable loss of liquid in 85.5 percent, slight loss in 10.4 percent, moderate loss in 2.2 percent, and marked loss in only 0.6 percent.

The results of this practical field test, combined with innumerable favorable reports received from canners for the 1936 canning season, substantiate the results of the laboratory tests and show that the fully sealed method of processing, as recommended, is a distinct improvement over the partially sealed method of processing as formerly advocated.

TABLE 4. — PRODUCTS PACKED BY COOPERATORS

Fruits:
- Applesauce
- Blackberries
- Blueberries
- Cherries
- Currants
- Fruit juices
- Fruit syrups
- Grape ade
- Grape juice
- Grape sauce
- Peaches
- Pears
- Plums
- Raspberries
- Raspberry jam

Miscellaneous:
- Mushrooms
- Pectin

Vegetables:
- Beans — lima
    - shelled
    - string
- Beets
- Broccoli
- Carrots
- Cauliflower
- Corn
- Peppers
- Pimentos
- Squash
- Tomatoes
- Tomato juice
- Tomato paste
- Tomato puree
- Vegetable soup

Meat and Fish:
- Beef broth
- Fish
- Fish flakes
- Ham
- Hamburg
- Lamb chops
- Meat
- Pork, roast
- Sausage
- Veal

Pickles:
- Beets, pickled
- Chili sauce
- Mustard pickle
- Pepper relish
- Piccalilli
- Sweet mixed pickle

Products canned most frequently

	Number of jars
Tomatoes and tomato products	5,565
Beans — shell, lima, string	2,584
Peaches	1,924
Beets	786
Corn	720
	11,579 or 70 percent of the jars packed

SUMMARY

1. Fully sealing all-glass jars prior to heat processing seems to answer the problems of reducing losses of liquid and improving general appearance of the product.

2. Fully sealing the jars, releasing pressure slowly, and leaving a large headspace decreased loss of liquid in pressure-processed jars.

3. An apparatus for the determination of pressures developed in all-glass jars during processing is described. The principal feature of this apparatus is an aluminum cover duplicating the glass cover.

4. In water-bath processing, the pressure developed in partially sealed jars was negligible. Fully sealed jars developed from 2 to 6 pounds pressure. Glass jars are strong enough to withstand this pressure without bursting.

5. In pressure processing, the pressures developed in partially and in fully sealed jars were similar, being within one pound of the retort pressure. The fully sealed jar took longer than the partially sealed jar to attain this pressure. Usually the rise in pressure of partially sealed jars corresponded to the rise in pressure in the retort.

6. There was practically no difference in the penetration of heat into jars of water either partially or fully sealed.

7. Two methods of determining vacuums in glass jars of food were compared. The vacuum desiccator method was perfected and gave accurate and consistent readings of partial vacuums in freshly sealed glass jars. The water displacement method was found to be reliable and checked with the former method.

8. The vacuums present in sealed glass jars were high, averaging well over 20 inches of mercury.

9. Temperature of filling, volume of headspace, and condition of seal before processing had no effect on the amount of vacuum formed in the jars after processing.

10. A practical survey of the use of the fully sealed method by 64 home canners who used a total of more than 16,500 jars to pack 50 different products, proved the practicability of this method in canning with all-glass jars. Of the jars packed, 85.5 percent had no noticeable loss of liquid. Tomatoes, beans, peaches, beets, and corn constituted the bulk of the products canned.

CONCLUSION

As a result of a two-year investigation of the vacuums and internal pressures of all-glass canning jars during heat processing and of practical cooperative experience involving over 16,500 all-glass jars, 50 canned foods, and 60 home canners, it is considered advisable to fully recommend sealing the jar by tightening the wire bail *previous* to thermal treatment (processing).

This method decreases markedly the losses of liquid from jars during processing, improves the appearance of the contents, saves time, obviates the necessity of handling the hot jars after processing, and has no effect on either breakage or spoilage.

REFERENCES

1. Clark, E. D., Clough, R. W., and Shostrom, O. E. 1923. Function of vacuum in canned salmon. Reprinted from the Pacific Fisherman. May, June, and July, 1923.
2. Ford, K. L. 1927. Vacuum — its measurements and its functions in the packing industry. Glass Container No. 6: 5–6 and 24.
3. Ford, K. L. 1930. General principles of retort operation. Glass Container No. 6: 5–7 and 36.
4. Ford, K. L., and Osborne, A. G. 1928. Heat transfer determinants. Glass Container No. 1: 7–8 and 34.
5. Levine, A. S. 1936. Some factors involved in the thermal treatment of all-glass containers. Master's thesis, Massachusetts State College. 55 p.
6. Maclinn, W. A. 1935. Some internal physical conditions in glass containers of food during thermal treatment. Master's thesis, Massachusetts State College. 30 p.
7. Maclinn, W. A., and Fellers, C. R. 1936. Vacuum determinations in all-glass canning jars. Food Research 1: 41–44.
8. Magoon, C. A., and Culpepper, C. W. 1921. A study of the factors affecting temperature changes in the container during the canning of fruits and vegetables. U. S. Dept. Agr. Bul. 956, 55 p.
9. Magoon, C. A., and Culpepper, C. W. 1922. Relation of initial temperature to pressure, vacuum, and temperature changes in the container during canning operations. U. S. Dept. Agr. Bul. 1022, 52 p.

Publication of this Document Approved by Commission on Administration and Finance
3m—4 '37 No. 468

140
3
342

GINIA POLYTECHNIC INSTI
GRICULTURAL BRANCH LIBRAR
BLACKSBURG, VIRGINIA

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No 342 April, 1937

FACTS
FADS &
FRAUDS IN NUTRITION

By Helen S. Mitchell and Gladys M. Cook

Present-day food advertisements make a tremendous appeal to a nutrition-conscious public which has only a very limited basis for evaluating the merits of the claims made. This bulletin is intended to serve as a guide to the consumer.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

CONTENTS

Page

Purpose and scope of this bulletin . . . 3

Food advertising . . . 4
  1. The proper type . . . 4
  2. Trick claims . . . 4
  3. Misleading testimonials or clinical reports . . . 5
  4. Educational versus pseudo-educational advertising . . . 5

Vague health claims . . . 6
  1. Health foods . . . 6
  2. Balanced foods . . . 7
  3. Food concentrates . . . 7
  4. Energy foods (cereals, candies, and fruit juices) . . . 7

Weight reduction . . . 9
  1. Metabolic stimulants for reducing . . . 9
    (a) Thyroid products . . . 9
    (b) Dinitrophenol products . . . 10
  2. Laxative salts and drugs for reducing . . . 10
    (a) Laxative salts . . . 10
    (b) Cathartic drugs . . . 11
  3. Specific foods or food concentrates for reducing . . . 12
    (a) Proprietary food concentrates for reducing . . . 12
    (b) Reducing claims made for common foods . . . 12

Laxative foods . . . 12
  1. Proprietary foods containing cathartic drugs . . . 13
  2. The laxative value of foods containing cellulose or other forms of bulk . . . 13

Aids to digestion and predigested foods . . . 13

Mineral foods . . . 14
  1. Legitimate mineral claims . . . 14
  2. Mineral deficiencies . . . 14
  3. Organic vs. inorganic minerals . . . 14
  4. Acidosis . . . 14
  5. Iron . . . 15
  6. Iodine . . . 15
  7. Extravagant mineral claims . . . 16

Vitamin claims in advertising . . . 17
  1. General vitamin claims — unwarranted . . . 17
  2. Specific vitamin claims may be legitimate . . . 18

Food combinations . . . 20

Disease cures and false therapeutic claims for foods . . . 21
  1. Acid stomach . . . 21
  2. Diabetes . . . 21
  3. Arthritis . . . 22
  4. Fasting cures . . . 23

Therapeutic claims for mineral or spring waters . . . 23

The quacks and how they operate . . . 24

Food legends . . . 26

Scientific opinions on food fads and quackery . . . 29
  1. Articles . . . 29
  2. Books . . . 30
  3. Sources of information . . . 30

Reference books on nutrition . . . 31

FACTS, FADS AND FRAUDS IN NUTRITION

**By Helen S. Mitchell, Research Professor,
and Gladys M. Cook, Research Assistant, in Home Economics***

PURPOSE AND SCOPE OF THIS BULLETIN

Material presented in this bulletin is not the result of original investigations by the authors but a summarization of information, decisions, and criticisms by recognized authorities concerning nutritional and therapeutic claims in food advertising as well as faulty concepts and notions regarding foods and nutrition. Most informative material along this line is published in journals or bulletins not readily available to the layman and consumer.

This publication attempts to present this information in brief and readable form so that the layman may answer for himself questions regarding extravagant, misleading food and nutrition propaganda. At the present time there is no adequate legal censorship of radio, newspaper, or pamphlet advertising. The United States Food and Drug Administration, the Postal Authorities, and the Federal Trade Commission may do all they can under the present laws to protect people against deceptively labeled foods, but they have little jurisdiction over advertising not attached to the product. It therefore behooves the consumer to develop a reasonable degree of skepticism as well as sales resistance in respect to extravagantly advertised health foods and fake nutritional claims. Intelligent skepticism must be backed by fundamental facts, however, because it is all too easy for the layman aroused by scare propaganda to go to the opposite extreme and doubt everything he reads or hears. It is quite impossible to include in a brief publication such as this bulletin specific answers to all questions which may arise or a complete list of false notions, food fads, fakes and fakers. A few of the more striking and popular misconceptions are considered, with specific names of products given only when federal or other reliable agencies have previously published their judgment or criticism. Some of the products may be off the market by the time this bulletin is published, but the general earmarks of false or misleading advertising will, however, become familiar to the reader and be easily recognized in the future. A rough classification of material presented has been attempted for the convenience of the reader. Footnote references may be consulted for authority on statements made or products mentioned. A brief comment regarding a proper scientific concept or definition of terms used introduces each subdivision of subject matter.

The Council on Foods of the American Medical Association publishes from time to time in the Journal of the American Medical Association *General Decisions* which have been adopted for its own guidance and that of the public, food manufacturers, and advertising agencies. These decisions are revised periodically as scientific progress warrants and are published in convenient

---

*Acknowledgment with thanks is made to Ruth deForest Lamb, Chief Educational Officer, Food and Drug Administration, U.S.D.A., who has read the manuscript and offered valuable suggestions.

VAGUE HEALTH CLAIMS

The layman should beware of so-called *health foods, perfectly balanced foods, scientific food concentrates* and other food products for which the makers claim curative or health-giving properties.

1. HEALTH FOODS

The Food and Drug Administration believes that —[2]

> . . . the use of the word *health* in connection with foods constitutes a misbranding under the Food and Drugs Act. The use of this word implies that these products have health-giving or curative properties, when, in general, they merely possess some of the nutritive qualities to be expected in any wholesome food product. The label claims on these products are such that the consumer is led to believe that our ordinary diet is sorely deficient in such vital substances as vitamins and minerals, and that these so-called *health foods* are absolutely necessary to conserve life and health.

The Food Law officials do not object to calling these products *wholesome* provided they are wholesome, but the effort to give the impression that we all need something added to our every-day diet if we are to avoid nutritional disaster is a misrepresentation which these authorities aim to combat.

The Council on Foods is even more explicit in defining the proper use of the terms *health, healthful,* and *wholesome.*[1]

> The term *health food* and equivalent claims or statements to the effect that a food gives or assures *health* are vague, misinformative and misleading. An adequate or complete diet and the recognized nutritional essentials established by the science of nutrition are necessary for health, but health depends on many other factors than those provided by such diet or nutritional essentials. No one food is essential for health; there are no *health foods.* Statements of well-established nutritional or physiologic values of foods are permissible.
>
> The term *healthful* is frequently encountered in food advertising. As used, it commonly means that the food described corrects a possible nutritive deficiency or some abnormal condition in such a manner as actively to improve health. It incorrectly implies that the food possesses unique (or unusual) health-giving properties. The term has a popular specific *health food* significance which makes its use in advertising misinformative and misleading.
>
> *Healthful* and *wholesome* by dictionary definition have almost identical meanings; the former, however, intimates an active significance, whereas, the latter signifies quality or condition. *Wholesome* indicates that a food so described is sound, clean, fit for consumption, and free of any objectionable qualities; it is appropriate for characterizing foods fulfilling these qualifications and should replace healthful as used in food advertising.

The same unwarranted claims made for patent medicines a few decades ago are made today by the manufacturers of "Health Foods." Weird concoctions of ground alfalfa or dried vegetables, inorganic salts, and flavoring are foisted on the unfortunate public as panaceas for every conceivable ailment, real or imaginary. As one commentator has said, "The ignorance of nutrition displayed by such promoters is equaled only by the extravagance of their claims."[3] One wonders whether such ignorance is sincere.

A single product may be recommended both for gaining and reducing weight, while at the same time it claims to "improve the complexion, feed the nerves, benefit teeth and bone development, build up blood, aid digestion." A certain beverage to be made with milk proclaims this *health* news: "is a builder of strong bodies, keen minds . . . steady nerves . . . essential in everyday life . . . a balanced food."[4] A so-called "cream bread" claims to be a "*health food* . . . because it is healthful. . . . It's the pure health-giving ingredients in every loaf that gives you the vitamins necessary to develop healthy bodies."[5] An example of many words which say nothing but influence many.

---

[1] Reference 1 on page 4.

[2] Press Service. U.S.D.A. May 22, 1929.

[3] Council on Foods. J.A.M.A. *108*, 47, 1937.

The Food and Drug Administration has published notices of judgment against several products making unwarranted *health* claims.

Catalyn (N.J. 21213)
Instant Alberty's Foods (N.J. 21210 and 24528)
Nature's Vital Food (N.J. 25116)
Ownen's Viti-Veg (N.J. 24963)

2. BALANCED FOODS

Vague *health* claims are frequently accompanied by the equally vague use of the term "scientifically balanced" or "balanced foods." No one food is expected to be taken alone or constitute a complete diet. When added to a mixed diet which may be good or poor, no one food can insure that the diet will become *balanced*. Beware of products advertising a "balanced composition."

One current radio advertiser unhesitatingly reiterates: "The including of ——— bread and baked goods in your menus assures well-balanced meals for every member of the family." Added to a meal consisting of other cereal products or starchy foods, even the best bread would detract from the nutritional balance of the meal, and certainly no "assurance" could be placed in bread as a "balancing" item in meal planning.

3. FOOD CONCENTRATES

The term *food concentrates* is to be distinguished from the term *concentrate* as applied to concentrated preparations of vitamins, flavorings, fruit juices, etc. Dehydration is a form of concentration and to that extent dried foods or milk powders may be considered concentrates, but that is not the usual use of the term.

Promoters of food mixtures consisting mainly of sucrose, malt extract, cocoa, and dried milk are prone to lay undue emphasis on the *scientific food concentrate* idea. These products are frequently wholesome and palatable and make an agreeable beverage but should not be relied upon for therapeutic purposes. Usually they are relatively expensive and no more nourishing than a home-made chocolate milk drink. They are not true concentrates.

The more erroneous use of the term *food concentrate* is its application to proprietary concoctions such as mineral mixtures, dried alfalfa, kelp, etc., which products are discussed later under *Mineral Foods.*

4. ENERGY FOODS

The misuse of the term *energy* is experiencing a wave of popularity among advertisers of cereal, candy, and other carbohydrate foods. The Council on Foods explain their stand on this question as follows:[1]

---

[1] Reference 1 on page 4.

[4] Committee on Foods. J.A.M.A. *105*, 120, 1935.

[5] Committee on Foods. J.A.M.A. *105*, 599, 1935.

> All foods except the simple mineral foods and water contain chemical energy available for use by the healthy body to support the many activities and life processes and incidentally to maintain temperature. The use of the term *energy* in defining the caloric energy value of foods should not be confused with the popular usage signifying activity, vitality, strength, vigor, or endurance. These conditions depend upon many factors, including freedom from disease, natural constitution, physical environment, training, habits, and others. Good nutritive condition, a necessity for health, requires far more than food energy only; all the nutritional essentials of a complete, well balanced diet, in adequate amounts, are demanded.
>
> Food advertising should correctly inform the public of the energy values of foods in carefully chosen terms that may be properly interpreted. The distinction between the caloric and popular senses of the word *energy* must be recognized and observed."

Some perfectly wholesome foods such as cereals have been widely advertised as perfectly *balanced* or *health-giving* or *energy* foods. The criticism of the advertising is not a criticism of the food as such, but of the misleading and extravagant statements made.

(a) **Cereals.** Some of the leading brands of our best cereals use such phrases as "a health food," "a richer source of energy," "double rich," "can do more for your child than any ordinary cereal," "keeps appetite normally eager," "richer in growth factors than any other cereal."[6,7] A current radio program claims that a certain bread "will put your youngster across the line between *good health* and *energetic vitality*." Another cereal[8] carries even more startling assertions: "a perfectly balanced food . . . an aid to digestion of other foods . . . required for maintaining a high degree of health and vitality." The trick wording and unwarranted claims are easily recognized. No cereal can be a "perfectly balanced" food nor "aid digestion of other foods." All cereals are good sources of calories and provide a moderate amount of protein. Whole-grain cereals provide certain minerals and vitamin B more than refined cereals. The difference in nutritive value between the different brands of the same cereal are insignificant except as to flavor and texture, which is a matter of choice.

(b) **Candies.** Certain candies have also indulged in *energy* claims to impress the public. Most candies have little to offer but calories. They are notably lacking in protein, minerals, and vitamins but they capitalize the caloric value of sugar as "a cheap source of energy," "concentrated energy for physical exercise." A five-cent candy bar advertised to school children as giving them more *energy* for their money than a wholesome five-cent item at the school lunch counter thwarts many an attempt to educate our young people in good food habits. The consumer must read between the lines if he is not to be misled by such statements.

(c) **Fruit Juices.** One widely advertised fruit juice also uses an *energy* story while another is emphasizing the *low caloric* (energy) content as an aid to reducing. Which is true? The one which says "quick energy breakfast . . . supplies morning energy" and neglects to state the large volume of fruit juice which would be necessary as an adequate source of *energy*, or the other whose reducing claims fail to inform the consumer that a reduction in total caloric intake is the all-important issue and that the juice in question may merely serve as one low calorie substitute.

---

[6] Committee on Foods. J.A.M.A. *104*, 922, 1935.

[7] Food and Drug Administration. N.J. 25851.

[8] Committee on Foods. J.A.M.A. *101*, 1229, 1933.

WEIGHT REDUCTION

The question of body weight is of general interest today. Not only has fashion decreed the slender figure, but life insurance figures show that excessive overweight reduces life expectancy. The medical profession recognizes the dangers of obesity and recommends safe and sane methods of weight control. Physicians are emphatic, however, in their warnings against indiscriminate weight reduction or the promiscuous use of commercial nostrums for this purpose.

Individuals showing a tendency to obesity fail to realize how small a quantity of food can influence weight. An intake of 100 calories (five teaspoons of sugar or one tablespoon of butter) a day above the energy expenditure may mean an increase in weight of 10 pounds in a year in persons inclined to obesity. The caloric intake must be lowered below the actual daily needs if the body is to draw upon its reserve supply of body fat. But restriction of energy intake must be accomplished without reduction of other dietary essentials. The intake of protein, minerals, and vitamins should be higher in proportion as the caloric intake is reduced. It is possible to plan such a diet which will be palatable and protect against the dangers of undernutrition without resorting to expensive dietary supplements or dangerous reducing nostrums. Intelligent people have already become skeptical of quack reducing remedies as is evidenced by lessening sales, but there are some who still need to be cautioned.

There are *three types* of reducing regimes which are or have been popular and should be recognized in their true light by the layman. The *true metabolic stimulants* are the most dangerous, the *laxative salts* and *drugs* are futile and often harmful, the *food supplements* with recommended *dietary regimes* are usually harmless but may be fraudulent in their therapeutic claims.

1. METABOLIC STIMULANTS FOR REDUCING

(a) Thyroid Products. Less than 5 percent of obese people have a true pathological obesity due to thyroid deficiency. Such cases are treated by thyroid extract carefully administered by a physician, guided by repeated examinations. Most cases of obesity due to overindulgence in food and too little exercise should not, however, be treated in this manner. Quack obesity cures are apt to contain potent drugs which are known to increase the rate of metabolism and thus burn up stored body fat and other tissues. The overweights are usually told that it is unnecessary to diet or exercise and that the product is *harmless* and will *improve* health. Serious and even fatal results have often been the outcome of such self-treatment for obesity.

A certain desiccated thyroid preparation marketed under a trade name has been on the market for over twenty-five years. It has repeatedly been on the docket of the Federal Trade Commission. The last action, taken as recently as January 1937, ordered the promoters to "cease and desist" from six different types of misrepresentation which are employed in their advertising. They were criticised for such misleading statements or misrepresentations as the following:[9]

---

[9] Federal Trade Commission. January 21, 1937. Docket No. 2406.

> "That thyroid deficiency is a common cause or the usual cause of obesity.
>
> "That all modern physicians use thyroid in the treatment of obesity.
>
> "That ——— or thyroid is the remedy indicated in and the best suited for the treatment of obesity.
>
> "That ——— or thyroid feeds the thyroid gland or stimulates or restores it to normal action.
>
> "That any weight in excess of the average weight is due to excess fat and that such persons should reduce and should effect the reduction by taking ———."

Reducing nostrums containing thyroid substance have been sold under a variety of trade names. These may state on the label in small and inconspicuous print that they contain thyroid substance. The newspaper or radio advertising of the same product may omit this valuable information and make far more extravagant claims as to its virtues for reducing. Label information is likely to be more conservative because the law has more teeth in enforcing reliability in labeling than in advertising. In spite of claims to the contrary, the advertising fails to disclose the potent and dangerous properties of desiccated thyroid and the necessary precautions for its use.

(**b**) **Dinitrophenol Products.** The drug *dinitrophenol* also increases the metabolic rate and causes a loss of weight but it is known to have an insidious and cumulative effect causing, in some people, vague and ill-defined symptoms, in others, a specific injury to the lens of the eye resulting in rapid cataract formation. There is no law to control the sale of products containing this drug but recent publicity regarding the dangers accompanying its use have materially reduced sales of such products. Reliable druggists realize the hazards of the promiscuous sale of such a drug and advise against its use. A list of trade-named products containing *dinitrophenol*[10] as an active ingredient follows:

Dinitrole
Dinitrolac
Dinitronal
Dinitriso
Dinitrose
Formula 281
Nitra-Phen
Nitromet
Nox-Ben-Ol
Prescription No. 17
Redusols[11]
Slim (N.J. 25042 and 25850)
Tabolin

2. LAXATIVE SALTS AND DRUGS FOR REDUCING

(**a**) **Laxative Salts.** Common laxative salts sold under a variety of fancy trade names, or laxative drugs sold as harmless remedies, or hidden in so-called *reducing foods,* all accomplish similar results — the loss of large volumes of water through the stools. The sudden weight reduction is due to loss of *water,* not *fat,* and both the water and the resulting weight will be promptly regained as soon as water is consumed. Furthermore, permanent injury to the intestine and digestive function may result from the repeated use of such drastic treatment. Proper laxative agents have their place in medical practice, but not as *obesity cures.*

Extravagant and ridiculous claims regarding the therapeutic value of such products are made in the advertising literature offered to the laymen. The laxative *reducing* salts are usually mixtures of some of the following: Glauber's salt, Epsom salt, baking or washing soda, table salt, potassium chloride, tar-

---

[10] Current Comment. J.A.M.A. *105*, 804, 1935.

[11] Bur. Inv. J.A.M.A. *106*, 1587, 1936.

taric or citric acid. One such popularly advertised product claimed to be a "superb combination of six separate mineral salts which help glands, nerves and body organs to function properly. . . . it strikes at the usual *CAUSE* of fat." This same nostrum was advertised in the British Isles as a producer of "vim, vigor and vitality" for men, but when it came to the U. S. A. it became an obesity cure for women. Another similar product advertises: "Now if you are fat you can eat your fill and yet grow thin . . . by the new ——— method of reducing. You can lose as much as seven full pounds the first week and look pounds lighter from the first day."[12] "——— is urged as a poison-banishing agent . . . to *eliminate body moisture* and unhealthy bloating . . not as a reducing one." Still another offers false encouragement with vague medical endorsement. "Now you can reduce 2 to 4 lbs. in a night . . . eat what you please . . . Excess weight has been removed, skin more lovely, bodies more shapely and minds brighter. . . . Your physician will tell you that ——— is certain to do the work and is absolutely harmless. . . . ——— will help your body throw off worn out fat and bodily poisons."

The Food and Drug Administration has taken action against two such products, Dieto (N.J. 22669) and Sleepy Salts (N.J. 21537). They severely censure such statements as "eat big meals, yet see the inches melt away" and "how to lose fat quickly, without drugs, without starving and no violent exercise." There are many other similar products being advertised over the radio and in the press which deserve equally severe censure.

(b) Cathartic Drugs. Laxative or cathartic drugs have much the same physiological action as the laxative salts. The ones most commonly employed in reducing nostrums are phenolphthalein, cascara, senna, and licorice.

The Post Office Department has issued a fraud order against Snyders Reducing Products sold as Snyders Anti-Fat Tablets.[13] The government analysis found this product to contain 85 percent chalk, 4.8 percent common salt, and ⅛ grain of phenolphthalein per tablet, with traces of other material. The advertising, which was accompanied by a picture of a slender girl in a bathing suit, reads: "I reduced 70 lbs. . . . Many women report the loss of as much as five pounds in *one week*, safely without drugs, dopes or chemicals, without strenuous exercise or dieting. ——— are Safe, Harmless, Effective. . . . does not leave a flabby skin. . . . A Triumph of Medical and Pharmaceutical Science."

Re-Duso and Berner's Tablets, sold by Re-Duso Sales Co. and Berner Sales, were barred from U. S. Mails July 8, 1936,[14] for engaging in a scheme for obtaining money under false and fraudulent pretenses. These tablets contain cascara as one of the active ingredients. They claim to ". . . eliminate excess fat by reducing the appetite and giving a very gentle and mild laxative action, causing the most natural elimination of excess fat and waste matter accumulated in the system." They "simply offer you an economical way to do what modern doctors do in treatment of obesity . . . "

Various other reducing remedies have been criticised or condemned by authorities only to be replaced by similar products under new names to deceive the unwary victim. An amusing and informative article on the subject of obesity cures is recommended for those interested.[12]

---

[12] Cramp, A. J. Hygeia, January 1935, page 50.

[13] Bur. Inv. J.A.M.A. *107*, 370, 1936.

[14] Bur. Inv. J.A.M.A. *107*, 1405, 1936.

3. SPECIFIC FOODS OR FOOD CONCENTRATES FOR REDUCING

A third type of obesity treatment bases its entire success upon the dietary regime recommended, which, in some cases, may be quite satisfactory. The food or food concentrate offered is not essential to the reducing program outlined.

(a) **Proprietary Food Concentrates for Reducing.** Many of these so-called *food concentrates* or *powders* consist of dry milk, cocoa, starch, dextrine, sugar, soya bean flour, and salt. All of these are harmless ingredients but none could possibly produce the reduction in weight claimed by the advertisers. Unwarranted therapeutic or curative claims as well as false statements regarding the mineral and vitamin content of such products are common offenses. The Food and Drug Administration has issued notices of judgment against certain widely advertised reducing systems.

Dietene (N.J. 24069 and 24527)
Stardom's Health Diet (N.J. 24519 and 25828)
Stoll's Diet-Aid (N.J. 23271)
Syl-Vette (N.J. 21746)

(b) **Reducing Claims Made for Common Foods.** Fruit juices, candies, and other common foods are recommended from time to time by promoters as specific aids to reducing. Some have no place in a reducing diet, others are truly low caloric foods which may logically constitute a part of a sane reducing regime. If these foods are accepted as agreeable adjuncts to a low caloric diet without false confidence in their reducing powers, no harm is done by using them. The advertisements leave the impression, however, that the food in question exerts a positive effect in promoting weight loss. From this standpoint only is the current advertising criticised; they are still wholesome foods to be used freely by all who like them. The consumer is warned, however, against such pseudo-scientific statements as [15, 16] "Yields quick energy" but is "never fattening," "Modern science discovers ——— burns up fat," "simple sugars are quickly absorbed and used and hence not stored as fat."

A wholesome cereal product has recently promoted a radio advertising campaign in which the slender figure of certain movie stars is the major appeal. The food has no specific reducing properties and is itself a carbohydrate food. Such advertising is grossly misleading and destroys confidence in food advertising in general.[17]

LAXATIVE FOODS

The control of chronic constipation is commonly attempted by self-medication. This practice can be neither condemned nor endorsed without knowing the cases in question. No attempt will be made here to discuss the relative merits of laxative or cathartic drugs. There are certain principles that should be understood, however, regarding the so-called *laxative foods* which are on the market. In general, they fall into two classes — those foods to which a cathartic drug has been added, and those which provide cellulose or some other form of bulk.

---

[15] Council on Foods. J.A.M.A. *107*, 660, 1936.
[16] Committee on Foods. J.A.M.A. *102*, 292, 1934.
[17] Committee on Foods. J.A.M.A. *105*, 1773, 1935.

1. PROPRIETARY FOODS CONTAINING CATHARTIC DRUGS

The Food and Drug Administration regards phenolphthalein or any other such laxative drug as an adulterant when it is used as an ingredient of a food. They say that "a powerful coal-tar cathartic has no proper place in bread or any other product sold as a food." In this respect Ownen's Original Laxative Health Bread, Viti-Veg, has been criticised by the Food and Drug Administration (N.J. 25587) as well as by medical authorities.[18]

2. THE LAXATIVE VALUE OF FOODS CONTAINING CELLULOSE OR OTHER FORMS OF BULK

Constipation due to stagnation or lack of bulk will frequently yield to regular habits and ample roughage. On the other hand, constipation may be due to causes other than those of dietary or roughage origin. Medical authorities[19] advise that cases of constipation not yielding to the regular use of foods providing considerable roughage should be under the care of a competent physician.

The laxative value of wheat bran is due to its fiber content. Any whole-grain cereal, vegetable, or fruit containing cellulose may contribute the necessary bulk to the diet — the latter being less irritating than bran.

Several varieties of prepared bran or bran cereals on the market have been criticised for too sweeping statements made regarding their laxative value.[20, 21] Some people following the advice of such advertising have ingested more fiber or cellulose than their systems could tolerate and the resulting injury has brought condemnation to bran. Bran is not a cure-all but it may be used in moderation by those who need additional bulk in their diet. Scientific observations on the laxative action of bran may be consulted for more detailed information.[22, 23]

AIDS TO DIGESTION AND PREDIGESTED FOODS

Foods which are easily digested cannot be said to aid in the digestion of other foods. *Partially digested* or *predigested foods* are of questionable value because the carbohydrate ingredient is the one usually concerned in such proprietary products and this very carbohydrate portion of our food is the least likely to need *predigesting*. Claims regarding *aids to digestion*, or *natural digestive* elements are also unwarranted.

The normal person is able to digest the constituents of common foods unaided by artificial means. Any child or adult can digest starch. Saliva swallowed with the food is more potent for digesting starch than any food containing malt or malt extract. Foods containing diastase do not aid in the "digestion of other foods" and have no action whatever on proteins and fats.

Beware of products claiming to be "predigested" or "aids to digestion." The misleading statements are easily recognized when one knows the earmarks[24] — "a special food property that has the power to aid in the digestion of starch foods," "increases digestibility," "a predigested complete food," "especially good for growing children."

---

[18] Committee on Foods. J.A.M.A. *104*, 1708, 1935.

[19] Council on Foods. J.A.M.A. *107*, 874, 1936.

[20] Committee on Foods. J.A.M.A. *104*, 1604, 1935.

[21] Council on Foods. J.A.M.A. *107*, 1303, 1936.

[22] Cowgill, G. R., et al. J.A.M.A. *98*, 1866, 1932; *100*, 795, 1933.

[23] Rose, M. S., et al. Jour. Amer. Diet. Ass. *8*, 133, 1932.

[24] Committeee on Foods, J.A.M.A. *97*, 1798, 1931; *105*, 120, 1270, 1271, 1935.

MINERAL FOODS

Recent research work on the mineral requirements for normal nutrition has added greatly to our fund of knowledge in this field. A study of the numerous functions of the various minerals in the animal body would be a maze to the uninitiated. But the quacks and unscrupulous advertisers would make it still more complicated by unwarranted statements regarding the *health-giving* and *therapeutic* value of minerals. Many of these advertising statements are vague and nonspecific, signifying or implying the presence of *all* the nutritionally valuable minerals in a single product. Such vague statements are not informative and are misleading.

1. LEGITIMATE MINERAL CLAIMS

Mineral claims made for any food should specify the individual element or elements present in nutritionally significant amounts. Minerals present only in traces in the amounts of food likely to be consumed in the diet do not warrant mention.

2. MINERAL DEFICIENCIES

Some advertisers not only make sweeping statements regarding the mineral content of the product in question but lead the reader to believe that the average individual is suffering from *serious mineral deficiencies* which can be made good only by the proprietary remedy or the food advertised. Smatterings of facts are intermingled with falsehood giving the entire copy a semblance of truth.

3. ORGANIC VS. INORGANIC MINERALS

There is no scientific basis for maintaining in general that *organic* mineral compounds are better than *inorganic*. In some cases the facts are quite the reverse. The quack tries to impress the public with repeated reference to *organic minerals* when in reality most of the mineral elements present in these proprietary compounds are inorganic. The availability of a mineral for animal nutrition is not dependent upon the organic vs. inorganic state but upon solubility and other chemical factors still under investigation.

There is no scientific conservatism in such quack statements as "Lack of food minerals in the diet in proper form . . . result in obesity, goitre, rickets, nervousness, anemia, eczema, asthma, rheumatism, neuritis, arthritis, and many female troubles." "Guaranteed to contain all essential minerals." "Minerals . . . necessary to maintain intelligence."

4. ACIDOSIS

Acidosis is always prominent among the dangers listed as resulting from mineral deficiencies. The quack uses the scare motive freely in discussing the dire consequences of an "acid system" and its widespread occurrence. Actually acidosis is a rather rare condition of the blood; it is not a common disease because the normal body has the necessary mechanism for disposing of excess acids and alkalies. There is little need for worrying if the diet is reasonably well balanced. Money spent in treating such imaginary ailments is usually wasted. When true acidosis does accompany some other disease, it is a problem for scientific management. Yet advertisements for these so-called mineral foods (most of which are not *foods* at all) use such unqualified and vague comments as "organic mineral salts necessary for an alkaline balance," "neutralize acids found in most deficiency diseases." Notices of judgment have been published against the commercial products Kal (N.J. 24056) and Vegetrate (N.J. 25574) for just such unwarranted curative and therapeutic claims.

5. IRON

Iron for blood building is recognized as a human nutritional requirement not always adequately provided in the poorer type of the average American diet. The quack carries this concept still further and points out that most people suffer from an iron deficiency and that his product is absolutely necessary as a source of the proper type and amount of iron. The truth is that foods vary considerably in their iron content and in the proportion of iron which is available. Investigations still in progress are attempting to determine the availability of iron in our common foods.

The whole process of blood regeneration is complex, involving other factors than the iron content of the food. Nutritional anemia is a condition in which the blood is deficient in hemoglobin. It may be due to an inadequate diet, but pathologic conditions may also be involved. Anemia and blood regeneration is a problem requiring intelligent scientific treatment. Blood-building claims, therefore, should be excluded from popular food advertising and certainly not taken seriously by the consuming public.

6. IODINE

Iodine is a chemical element essential for normal nutrition. Simple goitre may develop in individuals living where food and water are deficient in iodine. The prevention of goitre in these areas by regularly administered iodine in some form is considered a nutritional problem, but treatment of a well-developed goitre requires a more professional approach.

(a) **Iodine Prophylaxis.** Iodine prophylaxis is conveniently accomplished by the addition of a definite amount of sodium or potassium iodide to common table salt (1 part in 5,000). Iodized salt is available in most groceries at no extra cost. The fortification of foods other than table salt with iodine or iodine compounds is not recommended by scientific authorities. The promiscuous addition of iodine to that naturally present in foods is unnecessary and may lead to excessive iodine intake and endanger health.

(b) **Exploitation of Iodine.** Iodine is popularly heralded in many proprietary and some natural food products as a general panacea for chronic human ailments. The therapeutic value of iodine may be more varied than science at present appreciates, but extravagant and vague claims are unwarranted.

Dried seaweed or kelp is an ingredient of many of these proprietary products. Kelp is rich in inorganic constituents among which iodine is conspicuous, but there is no scientific basis for attributing magic powers to kelp. Several kelp products have been declared false and fraudulent by the Food and Drug Administration because of such unwarranted therapeutic claims as "anti-infective, anti-sterility, life giving, growth promoting" and as cures for almost any disease one can name: constipation, stomach disorders, indigestion, nervousness, female troubles, neuritis, obesity, underweight, skin diseases, anemia, fatigue, goitre, headache, rickets, arthritis, kidney disorders, heart trouble, and many more. Sometimes the list is so long it needs to be given in alphabetical order to assist the reader in finding his pet ailment. The Food and Drug Administration has issued notices of judgment against the following kelp or sea weed products for false therapeutic claims:

Hauser's Potassium Broth[25]
Kelp-A-Malt (N.J. 22338)
Kelfood (N.J. 22601)
Parkelp (N.J. 20911)
Seavigor (N.J. 24085)
Vegetrate (N.J. 23260 and 25574)

7. EXTRAVAGANT MINERAL CLAIMS

It is entertaining and enlightening to review a few of the extravagant claims which have been made for some of these so-called *mineral foods.* They claim to "banish all acid condition of the stomach," "purify the blood," "aid elimination," "restore every gland and organ in the body to perfect functioning," "remineralize your body." Usually exorbitant prices are charged for a cheap mixture of minerals, dried alfalfa, grains, etc., with numerous false or misleading therapeutic claims. One company gives an alphabetical list of over 200 diseases and conditions all of which may be relieved or cured by one of their 12 mineral foods.

Notices of judgment have been published against Burbank Tea (N.J. 21199 and Nature's Mineral Food (N.J. 25091); and other similar products [26, 27, 28] have been severely censured by the American Medical Association.

---

[25] Radio Service. U.S.D.A. April 13, 1936.
[26] Bur. Inv. J.A.M.A. *103*, 1325, 1934.
[27] Committee on Foods. J.A.M.A. *104*, 219, 1935.
[28] Bur. Inv. J.A.M.A. *104*, 335, 1935.

VITAMIN CLAIMS IN ADVERTISING

Popular interest in vitamins may be partly the cause and partly the result of the extensive use of the vitamin appeal in advertising. The subject is nutritionally important and as such deserves attention from the consumer. Some of the agitation for an increased vitamin content of the daily diet is proper and beneficial. The use of more fruits, vegetables, and whole-grain products is encouraged as a means of increasing the intake of various vitamins. In fact there is no serious objection to the reasonable fortification of food products with vitamin concentrates or with natural foods rich in vitamins but, with few exceptions, there seems to be little necessity for such vitamin fortification. Nevertheless, advertisers tend to exploit the public by their *indefinite* and *general vitamin claims* for specific foods or food preparations. Such claims mean almost nothing unless the specific vitamin or vitamins are designated and unless the quantity of the factor present is significant.

The Council on Foods again finds it necessary to define a stand to be taken in the matter of vitamin advertising from which we quote.:[1]

> It is desirable that warranted vitamin claims be expressed in appropriate terms indicative of the relative potency of the food as a source of the vitamins in the dietary schedule. Foods may be considered relatively as fair, good and excellent or rich sources of vitamins. Statements of vitamin unitage in numerical quantities per gram (and per ounce if desired), where established, are to be encouraged on container labels and in advertising. The type of unit used should be specified.

1. GENERAL VITAMIN CLAIMS — UNWARRANTED

The various and startling therapeutic values ascribed to some of these so-called *vitamin concentrates* should arouse skepticism among any but the most gullible. Some of the products contain only traces of certain vitamins, while the advertising copy implies the presence of all vitamins in concentrated form. Vitamins A and C were absent from one product advertised as containing all known vitamins, while several with similar claims contained no appreciable amounts of any vitamin. The "health giving vitamins," which could not be discovered at all in one product, were purported to "enrich the blood . . . strengthen the nerves . . . increase weight and energy . . . aid digestion . . . correct constipation . . . clear the skin," and in general "act as a tonic in . . . run down conditions."

There is no intention of belittling the nutritive value of vitamins; but such false propaganda as that just cited makes the layman skeptical of legitimate claims which will be mentioned later. Several proprietary products have been publicly censured for unwarranted or misleading claims made with regard to their general vitamin content. Some others not listed here are subject to similar criticism.

---

[1] Reference 1 on page 4.

Chocco-Yeast (N.J. 21282)
Dennos Food (N.J. 21177)
Earle's Palatable Hypo-Col Tablets (N.J. 22370)
Jo-Lova Tea (N.J. 22602)
Malvitose (N.J. 25050)
Normalettes (N.J. 21198)
Mastin's Vitamon Tablets (N.J. 24118)
Nu-Vita Yeast (N.J. 20903 and 21581)
Thor's Vitamin Compound (N.J. 21189)

2. SPECIFIC VITAMIN CLAIMS MAY BE LEGITIMATE

Some comment seems to be necessary regarding the *justified* and *ethical* claims which may be made regarding *specific* vitamins and the abuses encountered in lay advertising. Again space prohibits an exhaustive treatment of this subject but some of the questions most frequently asked will be considered.

(a) **Vitamin A.** Vitamin A, found abundantly in natural foods such as dairy products, green vegetables, carrots, etc., is necessary for normal growth and health but need not be sought in expensive proprietary food preparations. One of the terms recently applied to vitamin A is *anti-infective,* implying that it increases resistance to infection. While there is ground for believing that an adequate amount of vitamin A is essential for the normal functioning of the mucous membranes of the respiratory tract, there is no assurance that an additional supply of this factor will prevent infection. Resistance to disease in general depends upon other factors than diet or any one dietary essential. Thus advertisements claiming that vitamin A or any other vitamin will protect against colds or respiratory infections are misleading although not absolutely false.

(b) **Vitamin B Complex.** This term *vitamin B complex* has come to be applied to a group of vitamins not necessarily similar in composition but associated in natural distribution. Several distinct fractions are recognized by research workers but from the standpoint of practical human nutrition, not more than two fractions, B (B_1) and G (B_2), need to be considered. Both are essential for normal nutrition but are easily obtained from common foods in a well-balanced dietary. B (B_1) is widely distributed in whole grains and vegetables; while G (B_2) is abundant in dairy products, eggs, meats, and fish. Both are present in yeast, which fact has given rise to undue exploitation of yeast products.

It is true that brewers yeast may be richer in vitamins B and G than bakers yeast, but the fresh moist yeast, if taken in sufficient quantity, may have more laxative effect than the dry yeast. Any type of yeast or yeast extract or product containing these is considered as a *special purpose food* and should be advertised as such. Many promoters of yeast products make unwarranted therapeutic claims.

(c) **Vitamin C.** Recent progress in vitamin C research has stimulated both scientific and popular interest to the point where overemphasis has become a danger. Formerly fresh raw fruits and vegetables were the only sources of this vitamin. Now it has been produced in pure crystalline form which may be used to reinforce foods or pharmaceutical preparations. This possibility opens the door to exploitation and fraudulent claims by unscrupulous advertisers. Ordinarily a liberal supply of fresh fruits and vegetables will supply the vitamin C requirement of a normal individual. If, as some scientific investigators indicate, there is need for temporary reinforcement with this vitamin in certain diseases, the physician may recommend a vitamin C concentrate produced by a reliable pharmaceutical concern. The consumer is warned to be skeptical of extravagant therapeutic claims for vitamin C preparations.

(d) **Vitamin D.** The relative lack of vitamin D in common foods and the possibility of the fortification of certain foods with this factor has become a matter of real concern to nutritionists and physicians. There is ample evidence that infants and young children, living in northern climates especially, need extra vitamin D. Older children and adults may also derive benefit from extra vitamin D. This factor may be supplied by one of several vitamin D pharmaceutical preparations — such as cod liver oil, halibut liver oil, or viosterol — produced by reliable concerns and accurately labeled as to unitage. Some children never receive any such supplement, however, and for this reason the fortification of certain foods with vitamin D may be desirable. The American Medical Association recently expressed the following opinion:[29]

> Of all the common foods available, milk is most suitable as a carrier of added vitamin D. Vitamin D is concerned with the utilization of calcium and phosphorus, of which milk is an excellent source.
>
> The properties of vitamin D may be imparted to milk by irradiation of milk, by proper feeding of vitamin D preparations to cows and by the direct addition to milk of either natural or manufactured vitamin D concentrates.

Most of the vitamin D milk now being marketed by reliable dairies is produced by one of these methods and is an acceptable and convenient source of this factor. The promiscuous reinforcement of a variety of other foods with vitamin D seems to be unnecessary and undesirable according to the American Medical Association. Those interested in this subject will do well to read the more complete discussion recently published in the Journal of the American Medical Association.[29]

(e) **Vitamin E.** There is no adequate scientific evidence demonstrating the role of vitamin E in human nutrition. Most of the experimental work with this vitamin has been done with rats and it is not even known that it applies to other animals. This vitamin is so widely distributed in common foods that it is even difficult to obtain a vitamin E deficient food mixture for experimental purposes. It is, therefore, evident that vitamin E reinforcement of the diet is both unnecessary and unwarranted and any product so advertised is to be regarded with skepticism.

(f) **Vitamin F** (?) A certain unsaturated fatty acid found widely distributed in common fats has been found essential for nutrition. Cosmetic manufacturers have adopted the term vitamin F for this substance but scientific authorities do not accept this nomenclature. Scientific research has demonstrated the need for this fatty acid in the *food* of a *rat* but evidence is lacking to prove its value in local *skin application for the human.* The Bureau of Investigation[30] has indulged in humorous satire in answering inquiries on the subject.

---

[29] Council on Foods. J.A.M.A. *108*, 206, 1937.

[30] Bur. Inv. J.A.M.A. *108*, 1279, 1937.

FOOD COMBINATIONS

A *Compatible Eating* fad, also known as the *Hay Diet*[31, 32] is one of the more recent of several movements for diet reform promoted by enthusiasts and endorsed by thousands of unwary converts. There is no physiological foundation for the belief that the various constituents in natural foods cannot be digested satisfactorily when eaten together at one meal. Rehfuss[33] has given us definite proof that proteins and carbohydrates are not incompatible, nor does an acid fruit interfere with the digestion of starch. Leporsky[34] has demonstrated that a combination of meat and vegetables may stimulate a better flow of digestive juices than either one alone. None of the dire consequences predicted as a result of eating the *wrong* combination actually materializes in the experience of thousands who boldly disregard such *warnings*. Be skeptical of scare advertising and of extravagant claims for the cure of disease by such weird dietary notions. Persons who have tried one of these new systems of eating and who claim to have been helped thereby may unknowingly have made other drastic changes in their dietary habits. The possible benefit seemingly derived from any of these regimes may arise from the fact that the variety of foods eaten is an improvement over the previous diet — more fruits and vegetables perhaps — rather than the eating of them in a prescribed order or combination. An adequate balance of needed food elements including minerals and vitamins is the important thing. The major emphasis if not the actual facts expounded by most self-styled nutritionists is misleading and holds out false hopes to the sick and ailing.

If you would be better informed on the futility and unscientific nature of these food combination fads, two humorous but reliable discussions of the subject are recommended. [35,36]

---

[31] Bur. Inv. J.A.M.A. *100*, 595, 1933.

[32] Current Comment. J.A.M.A. *104*, 402, 1935.

[33] Rehfuss, M. J.A.M.A. *103*, 1600, 1934.

[34] Leporsky, N. T. Jour. Diges. Dis. and Nut. *2*, 638, December 1935.

[35] Lieb, C. W. Hygeia, August 1936, page 683.

[36] Rose, M. S., Jour. Amer. Diet. Ass. *8*, 489, 1933.

DISEASE CURES AND FALSE THERAPEUTIC CLAIMS FOR FOODS

Perhaps the most dangerous of all food fads and quackery are those which claim to *cure* any or all of the list of diseases which are most puzzling to medical science; cancer, diabetes, arthritis, rheumatism, hypertension, arteriosclerosis, heart disease, and kidney troubles. Beware of any remedy advertised to cure these conditions. Medical science is spending millions in research on these diseases. Definite progress has been made and is being made and the public will benefit just as fast as this information can be put in the hands of reputable physicians. Valuable time and money are lost fooling around with quacks. In general, popular advertising dealing with the treatment of disease or the nutrition of the sick is considered scientifically unwise and undesirable. This practice promotes self-diagnosis and self-treatment for which the layman is not qualified, and thereby may endanger health and life.

1. ACID STOMACH

The *acid stomach* scare constitutes the quack advertising lingo for a number of digestive remedies and diet systems. The stomach is normally acid and necessarily so for adequate digestion of food. There is just as likely to be too little as too much acid in certain abnormal states, but careful diagnosis and medical advice is necessary in such cases. Yet the quack who encourages self-diagnosis and medication still persists in suggesting the *serious* results of *acid stomach* and offers "anti-acid," "relief of acid stomach," and "cures for acid indigestion."

2. DIABETES

There are a number of *diabetic remedies* or *treatments* which hold out false hope of cure to the diabetic patient. In addition, there are numerous products advertised as *diabetic foods* which are recommended as safe to be eaten by diabetics in any amounts.

(a) Ethical Diabetic Treatment. The diabetic patient whose disease is being controlled by diet or by diet and insulin under a physician's supervision should never relinquish this safe and reliable regime for any of the quack remedies advertised. Persons not under the care of a physician will find no short cut, cheap *cure* for diabetes among the advertised nostrums. The discovery of insulin and our present understanding of its use have taken the dread and hopelessness out of this disease although no real cure for diabetes is known to medical science. The story of diabetes and insulin is interestingly told in popular language by Joslin, [37] a recognized authority in this field.

(b) Fraudulent Diabetic Cures. The active campaign against diabetic nostrums waged by the American Medical Association [38, 39] and the Federal agencies has made many of them short-lived but new ones are continually cropping up. Several such nostrums or treatments are listed and discussed by A. J. Cramp[40] in an article which is well worth reading. Some of these nostrums are nothing more than chopped-up wild carrot (Queen Ann's Lace) which is one of many diuretics sold as *diabetic cures.* Wild carrot is irritating to the kidney, resulting in an increased excretion of urine. The catch is that the amount of sugar in any one specimen may be less because of the increased volume but the total sugar output for the day may be the same or actually increased. The spectacular testimonials which usually accompany such products are written either by the promoter himself or by some innocent victim whose death notice may have been published even before the *cure* testimonial appeared. The following phrases are characteristic of quack *diabetic cure* advertising: "Relief guaranteed," "Sugar free in 48 hours," "Sugar removed in easy nature's way," "Patients treat themselves," "Pleasant, easy, very successful." Notices of judgment have been published or other federal action has been taken against the following products:

---

[37] Joslin, E. P. Hygeia, January and February 1937, pages 37 and 168.

[38] Bur. Inv. J.A.M.A. *103*, 1639, 1934.

[39] Bur. Inv. J.A.M.A. *108*, 317, 1937.

[40] Cramp, A. J. Hygeia, October 1935, page 916.

Alberty's Anti-Diabetic Vegetable Compound (N.J. 21220)
Dia-Bet (N.J. 24660)
Diabeticine[41]
Diano for Diabetes (N.J. 20555)
Healthagain (a food medicine of vegetable origin) (N.J. 22025)
Warner's Safe Diabetes Remedy (N.J. 20901)

(c) **Diabetic Foods.** Not all *diabetic foods* are fraudulent or misrepresented. There are a number of reliable commercial companies producing *special purpose foods* useful for diabetics. These may be fruits canned without added sugar, products sweetened with saccharine, or breads and crackers of low carbohydrate content. Such ethical products are sold with a complete and accurate analysis on the label and may be incorporated according to their nutritive value as a welcome variety in the diabetic menu. They are not recommended as safe for diabetics in unlimited quantities nor are they a necessary part of a diabetic diet.

Criticism is aimed, however, at advertisers of so-called *diabetic foods* who give the erroneous impression that the flour or bread in question has remedial action and may be eaten by diabetics in unrestricted amounts. Unwarranted therapeutic claims have been made regarding several *diabetic foods*[42] chiefly of the gluten or legume flour type.

3. ARTHRITIS

The widespread and growing interest in arthritis is not difficult to understand when one considers the prevalence of the disease. Most cases of arthritis, no matter which type, are still baffling to the medical profession and there is no known cure or wholly successful therapeutic diet to be recommended. Published reports of clinical experience with various dietary regimes are conflicting. The following have been tried and found wanting:

1. Omission of so-called acid fruits and vegetables.
2. Use of only one type of food constituent at a meal (protein, fat, or carbohydrate).
3. Alteration of the acid-base balance of the diet.
4. Restriction to a low protein diet.
5. Reduction of caloric intake.
6. Restriction of carbohydrate in the diet.

A well-balanced, adequate, high-vitamin diet is now generally recommended by arthritis specialists. In view of the present state of knowledge regarding the treatment of arthritis it is futile to put one's faith in any regime or nostrum advertised as a *cure* for arthritis. There are plenty of such on the market, however, and more will continue to appear so long as the unfortunate sufferers from this disease continue to patronize them.

---

[41] Bur. Inv. J.A.M.A. *105*, 218, 1935.

[42] Committee on Foods. J.A.M.A. *102*, 538, 1934; *104*, 563, 1935; *105*, 1270, 1346, 1431, 1772, 1935.

4. FASTING CURES

Another age-old fallacy. Fasting regimes have been heralded as a cure for smallpox, appendicitis, pernicious anemia, colds, rheumatism, and so-called acidosis. To be sure there are digestive disturbances in which food becomes distasteful and may well be left alone until natural appetite returns, but there is no magic in fasting as a cure for disease. The fasting fad is much less popular today than it was a generation ago but occasional enthusiasts are still encountered.

THERAPEUTIC CLAIMS FOR MINERAL OR SPRING WATERS

Since the question of the supposed *health* value of drinking water from some special source occasionally arises, an authoritative answer to this question is in order.[1]

> Mineral, spring, natural or alkaline waters are usually advertised with unwarranted claims as to their health values. These waters are often alleged to possess curative and medicinal properties.
>
> Analyses of most of these waters do not disclose explanations or evidence for remarkable curative properties. In many cases the deceptive therapeutic claims are the result of hearsay and illusion, or of deliberate scheming to defraud.
>
> Formerly, therapeutic properties were attributed to mineral waters containing lithium or possessing radioactivity. Such characteristics as radioactivity or the presence of lithium in drinking water have not been shown to have useful effects. Strongly radioactive waters may be distinctly harmful. Natural waters contain only traces of lithium. The fortification of waters with lithium salts has no rational foundation; larger doses of lithium may be dangerous.
>
> Spring waters of low mineral content are not to be distinguished physiologically from ordinary potable tap or drinking water; their properties for meeting the water needs of the body are the same. Drinking water should be pleasing to the taste and free from contamination that may produce disease. Therapeutic or curative claims for mineral waters that are not laxative are to be viewed with suspicion.
>
> The daily water requirements for health cannot be defined with any degree of exactness, as activity, temperature and other conditions influence the demands. Sufficient water should be taken with meals and between meals to satisfy thirst. Glutting the body with water is not justified. Under disease conditions the physician should prescribe the water intake.
>
> Good bottled waters of uniform composition of tested purity and freedom from pathogenic contamination at the source and protected from possible contamination during transit to the consumer have special usefulness; they serve as refreshing, pleasing drinking water with a maximum safety assurance and merit the support of popular and professional advertising appropriate for pure potable water.

A pamphlet published by the Bureau of Investigation of the American Medical Association gives a list of several mineral waters which have carried misleading and deceptive advertising.[43] The Food and Drug Administration has published notices of judgment against two others: Witter Water (N.J. 21188) and Cal Spa Water (N.J. 20886).

---

[1] Reference 1 on page 4.

[43] Bur. Inv. A.M.A. Pamphlet — Mineral Waters.

THE QUACKS AND HOW THEY OPERATE

Morris Fishbein, editor of the Journal of the American Medical Association, has said that there is a sucker born every minute and a quack every hour to take care of the sixty suckers; that the old *patent medicine* quack used to reach his 10,000 while the modern *food* quack, using high-pressure methods, reaches his 100,000. The accuracy of these statements may be questioned but the implications are correct and worthy of attention. The public today is being exploited by food advertisers more than ever before. Laws can never control the situation completely; the consumer must be well informed and intelligently skeptical if he would protect himself.

The *food* quack today uses many of the same devices, modernized, which Wiley[44] encountered in fighting the *patent medicine* vendors a generation ago.

> Patent medicine makers and sellers hit upon every passing whim and fancy to advertise their goods. The microbe created quite a furor in the public mind, and the nostrums glibly guaranteed to *cure* the microbe in whatever form he might be or in whatever hiding place this monstrous creature might be found. Germs and bacteria replaced the microbe in the public interest and *medicines* sallied forth to attack germs and bacteria.

Wiley also encountered difficulties which are remarkably modern in tone.

> One of my hardest tasks in fighting the fake medical fraternity was to overcome the support given them by their own dupes and by the press. Testimonials were easily obtained for a price, as they are today for various products. Obscure and little-known *doctors* as well as preachers, teachers, and men and women in all walks of life, were exploited as endorsers of nostrums. The patent medicine manufacturers furnished a great bulk of the average newspaper's advertising, and therefore its income. Advertising contracts were held as clubs over the heads of the editors and publishers, and many newspapers were definitely under the influence of the quacks.

The typical food *quack lecturer* or pseudo *health promoter* usually has poise, personality and persuasion, which qualities assure him of a hearing and a goodly number of converts. His plausible arguments and glib use of scientific terms inspire false confidence. The letters usually found after his name may be fake degrees given by third-rate institutions sometimes founded for the express purpose of conferring the degree, or *bona-fide* degrees given by reputable institutions whose professional and ethical standards he has long since forsaken. His pseudo-scientific explanations of nutrition and physiology abound in quotations from authentic sources, sometimes misinterpreted, sometimes used correctly along with misleading statements to give the whole an air of authority. The insidious mixture of the true and false is always more difficult to interpret correctly than the glaringly false. The clever quack is well aware of popular interest in the scientific and he works accordingly. Of all quacks the *food faddist* is the most prolific because he gets the *biggest following* — his is a profitable business. He makes converts faster than scientific knowledge can be broadcast because the scientist is conservative and tries to be accurate — the food faddist quite the opposite. Put out of one state, he starts in another; put off the air in the United States, he starts up his own high-powered broadcasting station in another country and keeps on selling his products in the United States. There is less provision for censorship of radio advertising than of printed material sent through the mails.

---

[44] Wiley, H. W. Autobiography, Bobbs-Merrill Co., Indianapolis, 1930.

Mail-order quacks usually operate under a variety of high-sounding names. When they have *milked* a victim dry under one firm name, they later solicit him under another name (and perhaps from a slightly different address), so that he will not suspect that all the *come-on* stuff emanated from the same source. Recently the Post Office Department at Washington issued a fraud order against one concern operating under ten different titles.[45] Another quack[46] promoting a diabetic fraud started his campaign with a mail-order tabloid. If a victim responded to this advertising *bait* he received the first of a series of mimeographed form letters which gave testimonials and extravagant reports of *cures*. Then followed a series of form letters designed to break down sales resistance and allay the fears of the unfortunate victim. The nostrum, sold under various names, was a mixture of sedatives, stimulants, and laxatives.

Be skeptical of mail-order solicitations and *cheap advertising* of nutrition nostrums or disease cures. Reliable products will find a market through ethical channels. *Be skeptical of extravagant claims.* The consumer's best protection against fraudulent advertising is a fundamental knowledge of nutrition obtained from reliable sources. Dr. Bogert [47] has aptly expressed the nutritionist's attitude toward this problem in general.

> The fact is that food fads flourish because people want them. It makes little difference to the food faddist whether the particular dietary cult he follows incorporates a few grains of truth along with the dross or not; he is attracted to this cult because it satisfies some craving to try a novel dietary, to be in fashion, to attract attention by being unusual in diet, or from the desire to *do something* about his health. He may benefit by the simpler diet, more regular living, and especially through the belief that he will be helped, but this proves nothing as to the theories on which the cult is based, and the same results might have been more painlessly attained by other means. The food faddist represents a psychological type and often drifts from one dietary cult to another; as long as we have this type of people in such large numbers, diet fads and cults will persist and will be profitable to their originators.
>
> The way to a saner and better balanced judgment about diet lies, of course, through education as to the facts about foods and the body. Knowledge casts out fear and the food cultist trades on fear. Everyone should know the elementary facts as to what constitutes an adequate and balanced diet, along with a few common-sense rules about how diet should be adapted to body build, and how it needs to be altered to cope with adverse conditions like constipation or indigestion. Then people need no longer be bewildered as to what kind of diet to follow, nor agitated by food fads and fancies.

---

[45] Bur. Inv. J.A.M.A. *107*, 370, 1936.

[46] Bur. Inv. J.A.M.A. *108*, 317, 1937.

[47] Bogert, L. Jean. Diet and Personality, MacMillan, New York, 1934.

FOOD LEGENDS

One of the best popular food articles of recent date published in Fortune,[48] May 1936, and later reviewed by Readers Digest should be read by everyone interested in the subject. The author comments that:

> More food notions flourish in the United States than in any other civilized country on earth, and most of them are wrong. They thrive in the minds of the same people who talk about their operations; and like all mythology, they are a blend of fear, coincidence, and advertising.

Possibly some of your own pet theories are included among these food legend gathered from hither and yon and briefly answered here.

1. Q. Are celery and fish special *brain* or *nerve* foods?
   A. No! There is no such thing as a *brain* food. Even in starvation, nerve tissue is the last to be deprived of necessary nourishment.

2. Q. Is it dangerous to eat ice cream or *milk* and *sea foods* at the same meal?
   A. No! — provided the foods themselves are fresh and in good condition. Spoiled sea food alone may cause serious indigestion.

3. Q. Is it safe to eat *acid fruits* and *milk* at the same time?
   A. Yes! Milk is curdled as soon as it comes in contact with the acid gastric juice anyway and the combination of fruit and milk forms a more easily digested curd.

4. Q. Are *green* fruits poisonous?
   A. No! They may be digested more slowly than ripe fruits but they are not poisonous.

5. Q. Are *bananas* indigestible?
   A. No! A ripe banana (yellow flecked with brown) is well digested even by small children.

6. Q. Do *fruit seeds* cause appendicitis?
   A. No! Some people may find that certain fruit seeds aggravate constipation.

7. Q. Is *milk constipating*?
   A. No! Milk is not constipating in itself. It is so completely digestible that when it is the sole article of the diet, lack of bowel movement may result from lack of roughage. When green vegetables, fruits, and cereals are included in the diet in reasonable amounts, milk is a most wholesome and valued food.

8. Q. Are *honey* or *brown sugar* good sources of vitamins and minerals?
   A. No! Honey and brown sugar carry certain harmless *impurities* which give flavor and color. The small amount of mineral in brown sugar is relatively insignificant. There is no vitamin present in either honey or brown sugar.

9. Q. Are *raw* eggs more digestible than *cooked* eggs?
   A. No! Quite the opposite. Soft or hard cooked (not boiled) eggs are more digestible than raw eggs.

---

[48] Fortune, May 1936, page 86.

10. Q. Is *clear* coffee less harmful than that *sugared* and *creamed*?
A. The effect of caffein in coffee is not altered by sugar or cream.

11. Q. Is *fresh* coffee more *healthful* than *stale* coffee?
A. No! There is very little difference if any except that of palatability.

12. Q. Is there any ground for the statement that *smoking* aids digestion?
A. No! Quite the contrary. Smoking inhibits normal hunger contractions and the flow of gastric juice — desirable preparatory processes for normal digestion.

13. Q. Does an *athlete* need a *high meat diet*?
A. No! Muscular exercise demands an extra supply of energy foods mostly carbohydrate, not extra protein.

14. Q. Is *garlic* beneficial as a blood purifier or in the treatment of chronic diseases?
A. There is no clinical evidence for therapeutic value in garlic. Most of the so-called garlic tablets or remedies carry only enough garlic to give the odor.

15. Q. Can any one food be called a *complete* or *perfect* food?
A. No! Not even milk, which comes nearest to being an all-round food for children, provides all the essentials. Effort should be made to select a good variety of foods rather than one complete food.

16. Q. Does the use of *excess salt* cause Brights Disease?
A. No! In some cases of Brights Disease (or kidney trouble) the use of salt is curtailed in treatment; it may aggravate but not initiate the trouble.

17. Q. Are *egg whites* (albumin chiefly) injurious to the kidneys?
A. No! Egg albumin is not objectionable to the normal person and does not tend to promote disease of the kidney.

18. Q. Is the *banana* and *milk diet* just another reducing fad?
A. No! Bananas seem to give satiety value to a low caloric diet and the combination of banana and milk for two out of three meals may be a convenient and easy way to reduce.

19. Q. Is it proper to drink *water with meals*?
A. Yes! A moderate amount of water aids rather than hinders digestion.

20. Q. Can any one food be said to *purify* the blood?
A. No! This is a vague and meaningless expression never used in scientific literature.

21. Q. Can any one food *build up resistance*?
A. No! A well-balanced diet providing all necessary minerals and vitamins will promote the best nutrition possible, which in turn should increase resistance to infection.

22. Q. Is *raw milk* a cure or treatment for *syphilis*?
A. No! Scientific medicine finds no basis for this fallacy recently expounded by a prominent physical culturist.

23. Q. "Is milk cancer's ally?"
A. No! Medical and scientific authorities find no evidence to support this theory which was recently expounded in a popular nonscientific magazine article. A later issue of the same magazine carries an article by a well-known authority, refuting this theory.

24. Q. Is the *mineral* content of fruits and vegetables changed in form by *cooking*?
A. No! The form of the mineral is not changed. A small amount may be lost if the water in which they are cooked is not used.

25. Q. Is the nutritive value of *meat* lost by cooking?
A. No! The same nutrients are present in warmed-over meat as in freshly cooked. Certain methods of cooking may decrease the digestibility.

26. Q. Is it safe to leave food *standing* in *opened tin cans*?
A. Yes! If food is properly refrigerated no harm can come from the can.

27. Q. Is it safe to cook or keep *acid foods* in *aluminum* utensils?
A. Yes! Some foods may brighten or darken aluminum but the food is not damaged in any way. Traces of aluminum are not toxic to the body.

SCIENTIFIC OPINIONS ON FOOD FADS AND QUACKERY

The following journal articles and books which discuss various phases of the Food Fad problem in more detail are recommended for further reading. Hygeia — The Health Magazine published monthly by the American Medical Association — always carries reliable health and nutrition information in popular and readable form.

1. ARTICLES

1. Eddy, Walter H., Avoid Dietary Fads
Good Housekeeping, August, 1934, Page 106
(Reducing fads versus sane methods of reducing.)

2. Farren, Marion R., Foods Fads and Faddists
Hygeia, October, 1934, Page 885
(Why should we have food fads? An answer.)

3. Fishbein, Morris, Quacks and Quackery
Hygeia, July, 1936, Page 584
(Amusing and stimulating comments.)

4. Funk, Clarence J., Victims of Advice
Hygeia, December, 1936, Page 1070
(Some disastrous results from following unqualified advice.)

5. Gauss, Harry, Food Fads
Hygeia, March, 1935, Page 210
(Fads, the result of wrong conclusions based on faulty reasoning.)

6. Geraghty, E. M., Watch Your Diet
Hygeia, January, 1937, Page 32
(An article for those whose weight is right.)

7. Joslin, E. P., Diabetes, Doctors, and Dogs
Hygeia, January, February, 1937, Pages 37 and 168
(The story of diabetes and insulin.)

8. Lieb, Clarence W., The "Compatible Eating" Fad
Hygeia, August, 1936, Page 683
(Convincing evidence against this fad.)

9. Rose, Mary Swartz, Belief in Magic
Jour. Amer. Diet. Ass., Vol. *8*, 489, January, 1933.
(The origin of magic beliefs with humorous rebuttals.)

10. Stone, Willard J., Dietary Facts, Fads and Fancies
J.A.M.A. *95*, 709, September, 1930
(Food fads the result of misinformation, fostered by cultists.)

11. Winters, S. R., Public Enemies Number 1: Food, Drug and Cosmetic Racketeers
Hygeia, September, 1936, Page 832
(An eye opener to current frauds.)

12. Wonders of Diet
Fortune, May, 1936, Page 86
(Entertaining, reliable, and well illustrated.)

2. BOOKS

1. Cramp, A. J., Nostrums, Quackery and Pseudo-Medicine
   American Medical Association, 1937
   (A factual record of all types of quackery.)

2. Fishbein, Morris, Shattering Health Superstitions
   Horace Liveright Inc., New York, 1930
   (The editor of the Jour. Am. Med. Ass. speaks.)

3. Lamb, Ruth deForest. American Chambers of Horrors
   Farrar and Rinehart Inc., New York, 1936
   (An extensive and intensive analysis of misleading advertising. The efforts being made and difficulties encountered in attempting to establish adequate legal supervision and control.)

4. Pitkin, Walter B., Let's Get What We Want
   Simon and Schuster, Inc., New York, 1935
   (Stirs up the consumer to assert his rights against rackets of all types, not just food frauds.)

3. SOURCES OF INFORMATION

1. American Medical Association
   535 North Dearborn, Chicago, Illinois
   (Bureau of Investigation — Nostrums and Quacks)
   (Council on Food — Food Advertising)

2. Better Business Bureau, Inc.
   Crysler Building, New York City

3. Food and Drug Administration
   United States Department of Agriculture
   Washington, D. C.

(Courteous inquiry about specific products will be answered whenever reliable information is available.)

REFERENCE BOOKS ON NUTRITION

Always consult the latest edition available and if purchasing a book for your own use choose one which offers a late edition. The science of nutrition progresses rapidly; an old book cannot give you the up-to-date information.

1. Bogert. Nutrition and Physical Fitness
   W. B. Saunders, Philadelphia
   (Useful facts about nutrition expressed in simple language.)

2. Bogert and Porter. Dietetics Simplified — The Use of Foods in Health and Disease
   MacMillan, New York
   (An up-to-date scientific text covering normal nutrition, diet therapy, and cookery. Suitable for nurse, dietitian, or housewife.)

3. Chaney and Alborn. Nutrition
   Houghton Mifflin Co., New York
   (A scientific text book for college students.)

4. Cooper, Barber, and Mitchell. Nutrition in Health and Disease
   Lippincott, Philadelphia
   (An up-to-date reference book on normal nutrition, food selection, diet therapy, and cookery. Suitable for nurse, dietitian, or housewife.)

5. Graves. Foods in Health and Disease
   MacMillan, New York
   (An elementary text and reference book.)

6. Pattee. Practical Dietetics
   The Author, Mt. Vernon, N. Y.
   (A text book for nurses.)

7. Proudfit. Nutrition and Diet Therapy
   MacMillan, New York
   (A text book for nurses and dietitians.)

8. Rose. Fondations of Nutrition
   MacMillan, New York
   (The fundamental principles of human nutrition in non-technical language.)

9. Sherman. Chemistry of Food and Nutrition
   MacMillan, New York
   (Authoritative scientific discussion of the science of nutrition. Assumes a chemical and physiological background.)

10. Mitchell (formerly Thoma). Food in Health and Disease
    F. A. Davis Co., Philadelphia
    (A text book for nurses and student dietitians.)

Publication of this Document Approved by Commission on Administration and Finance
7m — 5-'37. No. 866.

FEB 28 '48 GINIA POLYTECHNIC INS
AGRICULTURAL BRANCH LIBRA
BLACKSBURG, VIRGINIA

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Bulletin No. 343 May 1937

VIRGINIA AGRICULTURAL EXPERIMENT STATION

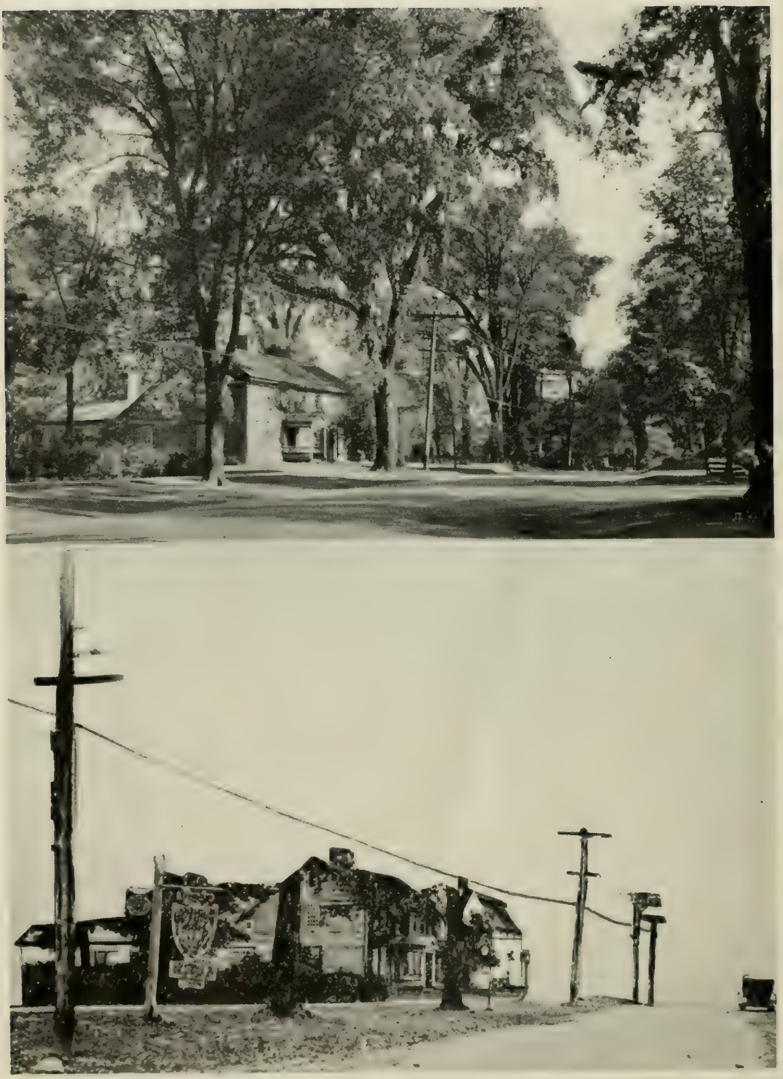
The Dutch Elm Disease

A New Threat to the Elm

By Malcolm A. McKenzie and William B. Becker

Although the Dutch elm disease has not been found in Massachusetts up to this time, nevertheless it constitutes a serious threat to the future of the State's principal shade tree. This bulletin is intended to supply basic information concerning the characteristics and spread of the disease.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.



Upper: Present-day Scene Along an Elm-shaded Street in a Massachusetts Town.
Lower: As the Same Street Would Appear if the Elms were Destroyed.

MASSACHUSETTS AND HER ELMS

Massachusetts cherishes her elms far beyond any monetary estimate which might be placed upon them, but some idea of the investment in dollars may help all of her citizens to appreciate more fully the true worth of her principal shade tree. In a recent elm census report, the value estimated for the elms in four Massachusetts cities and towns was conservatively placed at $7,300,000.

Far in excess of money value, in a hundred ways to which we seldom give a single thought, the elms of Massachusetts really contribute generously to the life, well-being, and happiness of the people throughout the State. If you have not already had occasion to appreciate the extent to which these trees affect your daily life and community associations, take a trip to some part of the United States where shade trees and particularly where elms do not adorn the streets and lawns of the communities. However, if you will, you can appreciate the value of your elms without traveling beyond the limits of your own city or town. Simply walk along one of your elm-shaded streets in midsummer and try to picture to yourself what effect the elimination of the elms would have upon your community.

Without the elms in Massachusetts one would find barrenness and desolation on the streets and commons instead of the charm that has become the legend of New England *with the elms.* Various ornamental structures for purposes of illumination might be installed as objects of beauty or otherwise to replace lost elms, but these graven substitutes are at best poor seconds for the natural beauty, symmetry, life, and shade of the elms.

The photographs on the opposite page show a present-day scene in a Massachusetts village street and the effect produced by altering a photographic negative to show the same view projected into a future day if our elms should be lost. Only by sustained vigilance can we hope to check any inroads that may be made against the elms by their new enemy — the Dutch elm disease — which is causing serious trouble within fifty miles of our State boundaries to the south and west.

THE DUTCH ELM DISEASE

A NEW THREAT TO THE ELMS

By Malcolm A. McKenzie, Assistant Research Professor of Botany and William B. Becker, Research Assistant in Entomology[1]

Since 1930, when the Dutch elm disease was first discovered in the United States, all persons interested in our principal shade tree have become increasingly alarmed as the number of elms known to be affected with this disease has steadily mounted. From 1930 to 1932 the known cases of the disease in America were limited to less than a dozen trees in Ohio. During the last three years, however, nearly 22,000 cases of the Dutch elm disease have been found in New Jersey, New York, Connecticut, Indiana and Maryland. Up to this time (May 1937) the disease has not been found in Massachusetts.

This publication aims to present to the people of Massachusetts the essential facts concerning the dread Dutch elm disease and to urge every one in the State to cooperate in the effort to protect and preserve our elms.

THE DISEASE

Distribution

As the name implies, the Dutch elm disease was first observed in the Netherlands; and, since the discovery by the Dutch in 1919, thousands of elms in European countries have been killed by the disease. Reports from Europe indicate that the disease exists throughout the extensive range of climatic and soil conditions included in the following countries: Netherlands, France, Italy, Austria, Belgium, Switzerland, Germany, Poland, Czechoslovakia, Balkan States, and Great Britain. The disease is widely distributed in England but has not as yet been found in Scotland.

In the United States, the most serious infestation of the disease at present is found on the eastern seaboard in New Jersey, New York, and Connecticut.

In both Europe and North America, the only continents where the disease has been observed, elms and trees of the closely related genus Zelkova are apparently the only hosts upon which the disease occurs in nature. A few species of elms are reported to be resistant to the disease, but none is known to be immune and the American elm (*Ulmus americana* L.) is very susceptible.

Investigation into the source of the disease in America led to the discovery, a few weeks after the finding of the disease in New Jersey, that burl-elm logs from Europe which were intercepted at the ports of New York, Baltimore, Norfolk, and New Orleans were carriers of the causal fungus. European elm bark beetles from which the fungus was isolated were also found to be present in the logs. It appears probable that at least fifty-eight shipments of elm logs which in some cases are now known to have been diseased and beetle-infested entered four ports of the United States from Europe during the period 1925 to 1934. These logs were delivered by rail to points in the Central and Midwestern States for manufacture into veneer products. Seven small centers of disease infestation have been reported as traceable to imported logs, in addition to the severe infestation in the New Jersey–New York area. Furthur importation of elm material is outlawed by present federal quarantine regulations.

---

[1] The writers are indebted to Profs. A. Vincent Osmun and Arthur I. Bourne, respectively in charge of botanical and entomological investigations, for valuable assistance, suggestions and criticisms during the preparation of the manuscript of this bulletin. Acknowledgment is also made to Miss Gladys I. Miner, Herbarium Curator, for the preparation of the photographic negative used in the lower half of the frontispiece; and to the Division of Forest Pathology, United States Department of Agriculture, and the New York State College of Agriculture, Cornell University, for the use of photographs wherever credited to these sources.

Symptoms

The disease may occur in an acute form evidenced by conspicuous, immediate, and severe wilting (Figure 1). Other cases in which wilting lacks the suddenness characteristic of an acute attack, have been described as chronic. In acute attacks, at first the young leaves and, within a short time, the leaves of the entire tree wilt and wither. If the wilting is particularly sudden, the leaves dry and curl before they turn completely brown or even while they are green. A short time after the wilting starts, the dried and curled leaves begin to fall and within a few weeks most of the leaves will have fallen. If the twigs wilt while they are still green, the retention of the end leaves and crooking of the twig tips are typical early symptoms (Figure 1, insert). The bark on the affected trees from which the leaves have fallen shows no immediate characteristic disease symptoms which would distinguish it from the bark of healthy trees. Within a short time after the leaves have fallen from diseased trees, however, scolytid beetles may infest the bark. The larvae of these beetles are frequently found in considerable abundance under the bark of trees recently defoliated. It is important to note that these beetles, when present under the bark, should not be considered as primary invaders inasmuch as the trees so infested have previously been weakened and usually seriously defoliated. An examination of the wood of such an infested tree should show additional disease characteristics if the tree has been affected by the Dutch elm disease. Frequent reports of observations of this kind have been made during the periods from June until late August.

The chronic type of the disease differs from the acute type mainly in the length of time required for the pronounced symptoms to appear on the affected trees. In some cases the entire summer may be required for the complete defoliation of a tree by this gradual process. During the relatively slow progress of the disease in such cases, individual branches bearing yellowed or wilted leaves, commonly called "flags," may frequently be observed in the tops or in other parts of the trees. Early dropping of the leaves which first showed discoloration is a rather common occurrence. It must be borne in mind, however, that not all early yellowing and wilting of elm leaves is caused by the Dutch elm disease since other diseases, certain insects, and some other types of injuries may cause defoliation.

In some cases "flags" may not appear in any part of an affected tree, but rather a gradual discoloration of the leaves over the entire tree may occur during the summer. The general appearance in such cases is like that of premature autumn coloration. Early defoliation of the entire tree or parts of it frequently results.

Still another chronic type of the disease has been observed in which the affected trees leaf out rather late or fail to develop leaves on some branches. The foliage may be sparse, chlorotic in appearance, and drop prematurely during the summer. The stag-head which eventually develops from the

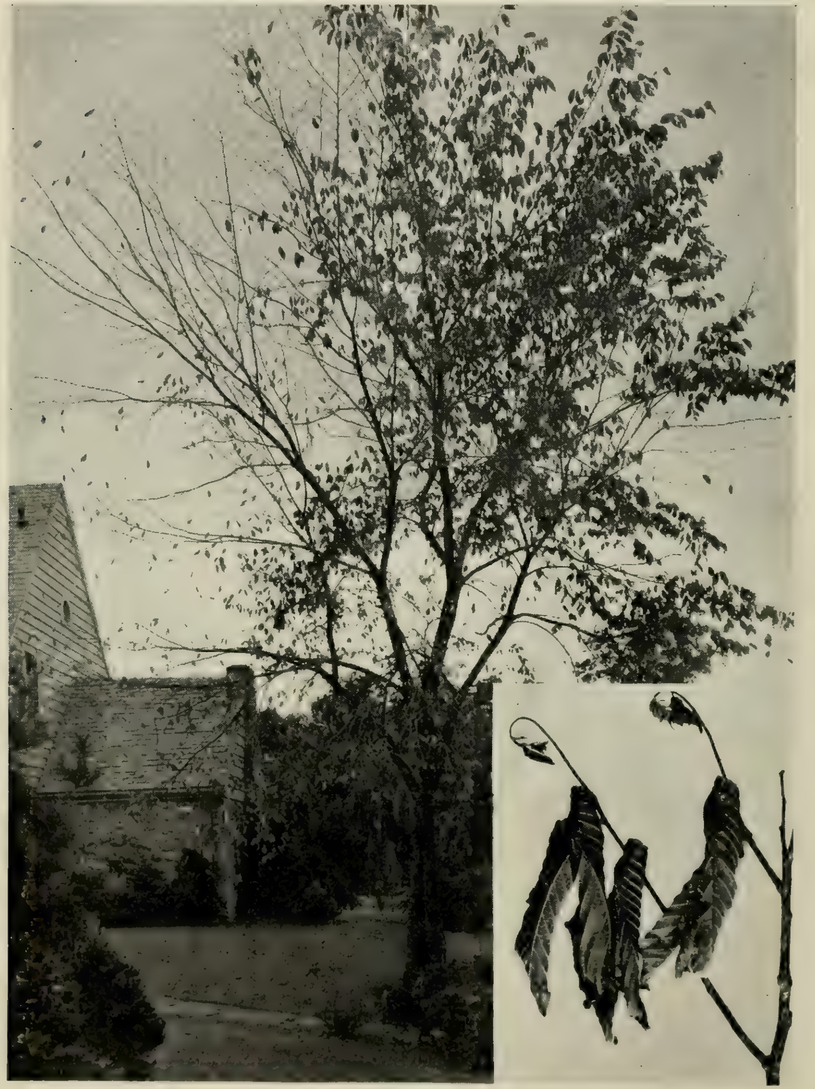


Figure 1. American Elm Affected with the Dutch Elm Disease.

Some leaves had wilted and others had fallen when photographed.

INSERT, LOWER RIGHT: **Tender Young Twigs of American Elm Showing Crooking of Twig Tips.**

Frequently the larger leaves fall early so that only a tuft of smaller ones remains at the tip.

(Reproduced from U. S. Dept. Agr. Circ. 322, pp. 4–5. August 1934.
Photographs furnished by Division of Forest Pathology, U.S.D.A.))

reduced annual growth in these instances is not to be distinguished from the stag-head commonly associated with various other troubles affecting elms.

Sometimes affected trees have been found in a group in which the disease had apparently spread from a central point.

The symptoms of the Dutch elm disease to be observed in winter are relatively few and not such as to be of much assistance in recognizing trees which are affected with the disease. Trees infested with bark beetles, trees which are stag-headed, trees which have dead branches, trees which show excessive suckering, and trees which fail to set flower buds or have dead leaf buds may be suspected of being affected with the disease, and the wood of such trees should be examined for further signs of the disease.

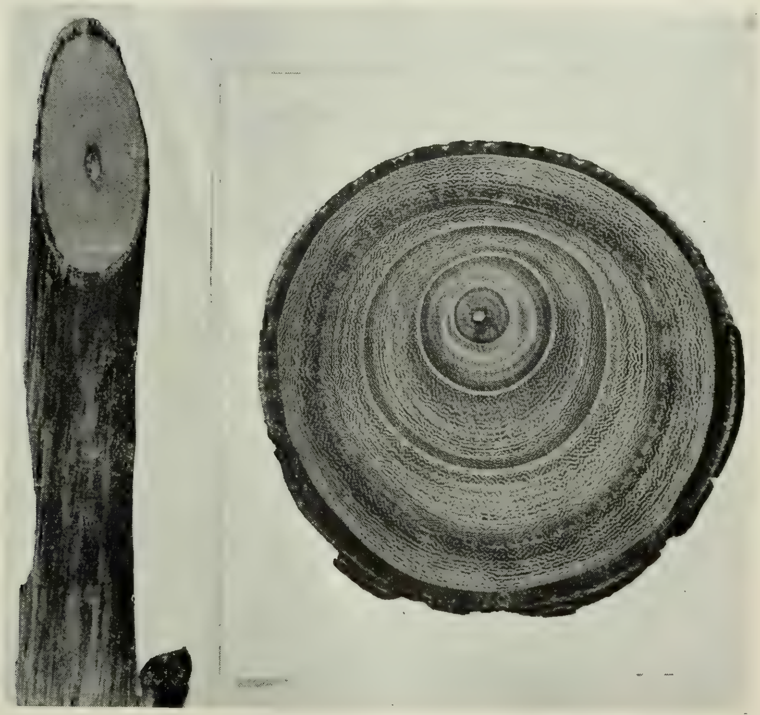


Figure 2. Diagonal and Cross Sections of Young Elm Twig and Branch Affected with the Dutch Elm Disease.

In the latter, the brown discoloration appears in the photograph as a dark concentric ring about ½ inch from the outside circumference of the outer bark. In the former, the discoloration is shown as an incomplete ring 1-16 inch interior to the limits of the cut surface of the twig. x1½.

A diagonal cut made through a twig affected with the disease shows a brown discoloration in the sapwood (Figure 2). Various patterns of discoloration may be associated with the disease. This darkened area may or may not be confined to one annual ring or a part of one annual ring; it may include the entire width of an annual ring or it may be limited to a narrow circle or semicircle in the spring wood, in the summer wood, or in both; and if it appears in more than one annual ring, these rings are not necessarily of successive years, but normal rings may come between those showing discoloration.

Peeling the bark will reveal the brown discoloration if such has been formed immediately under the bark in the last annual ring. However, peeling the bark of a tree that has formed considerable summer wood may show no discoloration whatever even though it has developed in the spring wood. Usually streaks appear in roots and large branches of trees as well as in the twigs, but discoloration may be somewhat restricted or even confined to a single branch. It appears that discoloration develops to a considerable extent in the sapwood of some trees before any external disease symptoms are noticed.

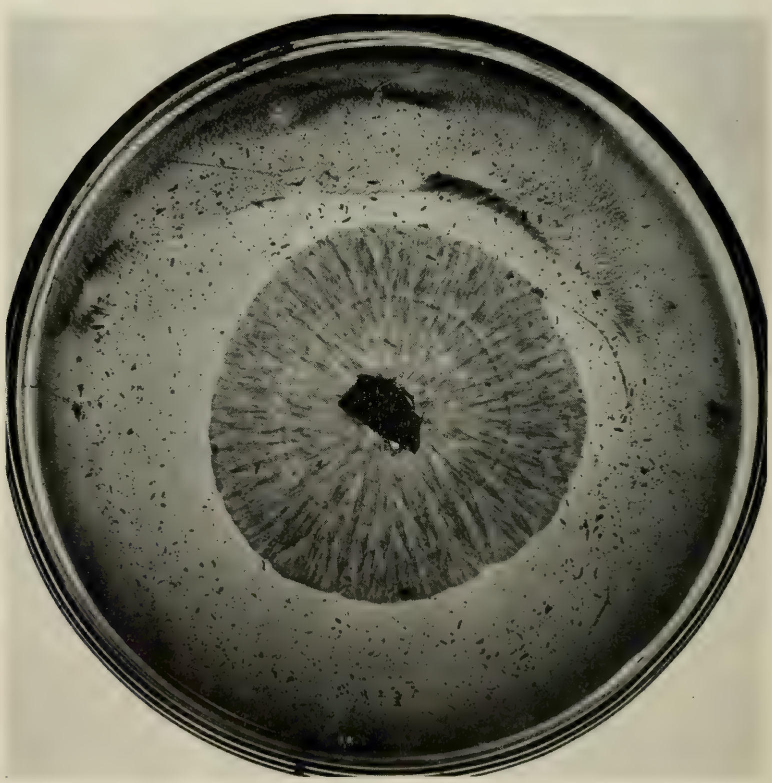


Figure 3. Young Culture of the Fungus which Causes the Dutch Elm Disease.
Grown from a tissue planting of discolored wood on potato-dextrose-agar medium. Actual size

A microscopic examination of a thin section of diseased wood shows the discoloration in the wood to be caused by the presence of brown substances in the water-conducting vessels, which are thereby plugged up, or in the immediately surrounding wood. However, a brown discoloration in wood is not limited to wood affected with the Dutch elm disease. Fungus organisms known to be associated with other diseases have been isolated from brown streaks and there may be other causes. Only a laboratory study can determine definitely whether the fungus which causes the Dutch elm disease is associated with any particular wood discoloration.

Causal Organism

The Dutch elm disease is caused by a fungus which lives in the sapwood. The fungus, first known in only its imperfect stage, was called *Graphium ulmi* Schwarz. Later, on discovery of the perfect or ascigerous stage, the fungus was assigned to the genus Ceratostomella, and the name became *Ceratostomella ulmi* (Schwarz) Buisman. The fungus can be distinguished from other fungi which cause similar wilting in elm by the type of growth and reproductive structures it produces in artificial culture media (Figure 3), and may be isolated in culture from infested trees at any time of year.

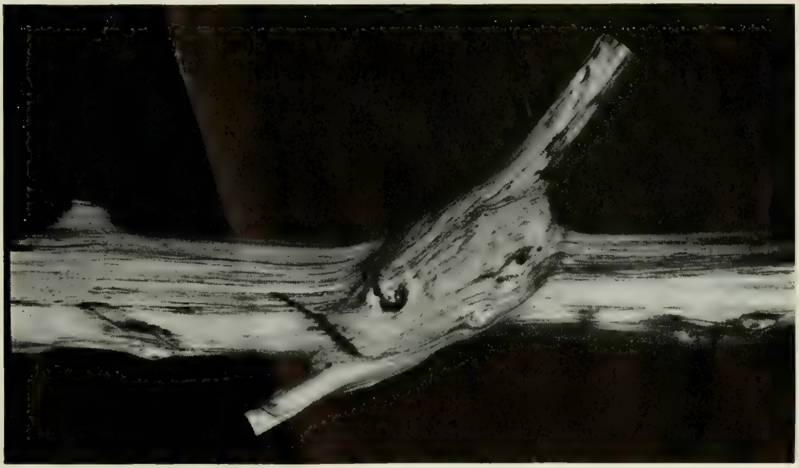


Figure 4. Roots of Two Elm Trees Grafted Together.

Bark removed to show streaks caused by *Ceratostomella ulmi* passing from one root into the other through the graft.

(Reproduced from Phytopath. 25: 1040. November 1935. Photograph furnished by Division of Forest Pathology, U.S.D.A.)

How the Fungus is Spread

The manner in which the fungus is disseminated is not completely understood. Numerous possibilities have been considered, including the following: wind, grafting, pruning tools, birds, and insects. At least one class of transmission agents has been established experimentally.

Wind. From the delicate nature of the spores, or reproductive units, of the causal fungus, it is apparent that these structures are not adapted to withstand the desiccation to which they would be subjected if borne by wind for considerable distances. Moreover, the fact that the fungus in its role as a vascular parasite is, for the most part, not accessible to air currents outside of the host definitely limits the possibility of direct spore dissemination by the wind.

Grafting. Contact of affected trees with healthy trees offers excellent opportunity for the spread of the disease within an area thickly planted to elms. It has long been known that elm branches when in close proximity and subjected to adequate pressure, will become grafted together. Likewise, elm roots in the soil may become grafted together. No better setup for the transmission of a vascular parasite could be devised than the natural condition of grafted roots, which phenomenon is doubtless widespread. In fact, trees affected by the Dutch elm disease have been found with their roots grafted together (Figure 4). Trees planted relatively closely along the banks of streams have been observed to be affected by the disease. Such observations agree with those for trees closely grouped elsewhere.

Pruning Tools. Pruning tools used in tree trimming operations have been considered a possible means of spreading the fungus. Persons engaged in trimming work, where the disease is prevalent, disinfect pruning tools to guard against the spread of the disease. This practice of disinfecting pruning tools is a good procedure in all tree trimming activities since, even when no serious diseases are known to be present, newly introduced or little understood parasites may be active, especially if dead branches are numerous.

Birds. It has been surmised that birds such as woodpeckers and sapsuckers may have a part in the spread of the disease, but there is no proof of this hypothesis.

Insects. From what is known of the distribution of the disease in America, it would appear that there are no agents of dissemination that carry the causal organism for very great distances. American and European elm bark beetles have been proved to be vectors of the fungus and there may be other carrier insects. Believed to be the most important of all carriers are the European elm bark beetles, one species of which is established in the United States. These insects are known to carry the spores of the fungus within and upon their bodies. For the most part, the flight of these beetles is limited to short distances. In some twenty-eight years since their first American discovery in Massachusetts, they have spread somewhat, but not alarmingly, within the State from the originally observed infestation.

Comparative data from recent authoritative experiments tend to indicate that prevailing winds are associated with the relatively long-distance travel of the beetles along the Atlantic coast area of infestation. It might happen, therefore, that beetles which carried the spores of the causal fungus could be wind-borne for some distance; but it is essential to remember that, for the most part, prevailing winds in the area mentioned are seaward and would not generally carry beetles great distances inland. Assuming that the beetles are the principal cause for concern in the spread of the disease, it is somewhat encouraging to observe that their further rapid spread inland along the Atlantic coast is at least partially precluded by natural conditions.

Only time can tell whether additional involved problems are connected with the spread of the disease and it is of utmost importance that laboratory and survey studies on the distribution of the disease and the causal fungus and its carriers be continued in an effort to obtain complete data.

CARRIER BEETLES

Of the elm bark beetles known to be carriers of the Dutch elm disease fungus in Europe, two are considered of prime importance: *Scolytus scolytus* Fab., the larger European elm bark beetle; and *Scolytus multistriatus* Marsh, the smaller European elm bark beetle. *Scolytus scolytus* is considered the more important of the two. In America, however, only *Scolytus multistriatus* is known to be established. It is now considered to be the most important insect carrier concerned in the spread of the causal fungus in the United States.

An elm bark beetle, *Hylurgopinus rufipes* Eich., native to this country, may, because of its habits, prove to be an important carrier. A recent report refers to *Scolytus multistriatus* and *Hylurgopinus rufipes* as the two important vectors of this disease in America.

The Smaller European Elm Bark Beetle

(*Scolytus multistriatus*)

This beetle was first found in the United States near Boston in 1909. A survey made in 1933 revealed the presence of the beetle in three rather large distinct areas around the cities of Boston, New York, and Philadelphia. It was undoubtedly introduced into this country at these seaports. Later surveys show that these infestations have enlarged.

In areas where the Dutch elm disease has occurred, there seems to be a definite relationship between the abundance of this carrier beetle and the prevalence of the disease. Because of this apparent relationship, the large infestation of *Scolytus multistriatus* in the Boston area causes some anxiety.

In a survey conducted by this Station in 1935, this beetle was found at two points in western Massachusetts. These new infestations appear to have extended from the New York infestation, which has spread up the Hudson River Valley beyond Albany and also to points in Connecticut not far from the Massachusetts line. Because the Dutch elm disease has spread into the New York area, the western part of Massachusetts should be kept under strict surveillance.

Description of Scolytus multistriatus. The beetle is about one-eighth of an inch long. It is shiny in appearance. The fore part of its body (head and thorax) is black, while the posterior part (elytra) is dark reddish brown in color. The ventral side of the abdomen (venter) slopes abruptly upward toward the rear and has a spine-like projection near the lower edge (Figure 5,A).

How the Beetle Spreads the Disease. The young beetles emerge from tiny shot-hole-like openings in the bark of logs or dying and recently killed elm trees. Some of these may be affected with the Dutch elm disease. Beetles emerging from bark of diseased wood often carry spores of the causal fungus on their bodies and in their digestive tracts. Flying to nearby healthy elms, they may feed upon small twigs, at leaf axils, and sometimes on the buds (Figure 6, upper right). Thus, emerging beetles which carry the spores of the fungus may inoculate trees through bark or bud punctures made in feeding. In this way, healthy elms may become infected. It is possible that wind currents may carry beetles considerable distances beyond their normal flights. In this way, it is not improbable that distant trees occasionally may be attacked by spore laden beetles, and the disease thus introduced into new localities. After feeding, the beetles fly to the trunks and larger branches of dead or weakened elms or to recently cut elm logs to lay their eggs in tunnels which they dig beneath the bark. These egg tunnels are made by the female beetles and are characteristically parallel to the grain of the wood and bark (Figure 6, upper left). They may be from less than one inch to about four inches in length. Eggs are laid close together along both sides of a tunnel. Tiny larvae or grubs hatch from the eggs and burrow more or less across the grain (Figure 5, C). They shed their skins several times as they grow. When full grown, they go through a transformation beneath the bark at the end of these side or larval tunnels, and become adult beetles. The young adults then dig out through the bark leaving the many shot-hole-like openings previously mentioned. When the beetles breed in diseased elms, many more individuals of the next generation will be carriers of the fungus, because the sticky fungus spores form abundantly in the brood galleries of diseased trees.

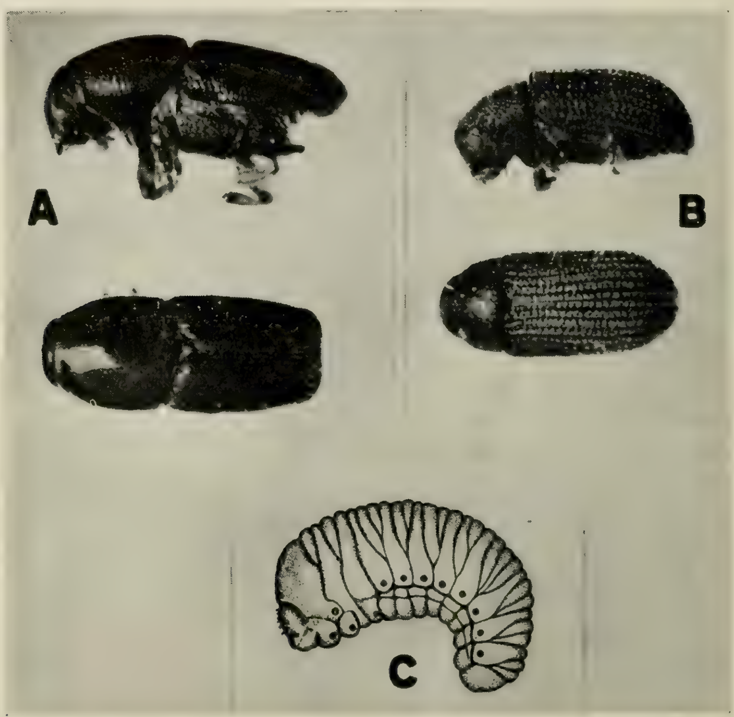


Figure 5. Beetle Carriers of the Dutch Elm Disease.

A. Side and top views of *Scolytus multistriatus* adult. Greatly enlarged.
B. Side and top views of *Hylurgopinus rufipes* adult. Greatly enlarged.
C. *Scolytus multistriatus* larva or grub. Greatly enlarged. (Reproduced from Cornell Ext. Bul. 290.)

NOTE: Grubs of *Hylurgopinus rufipes* are very similar to those of *Scolytus multistriatus*.

Several species of tiny mites which are considerably smaller than the beetles also live in these tunnels. Some of these may be carried to new trees on the

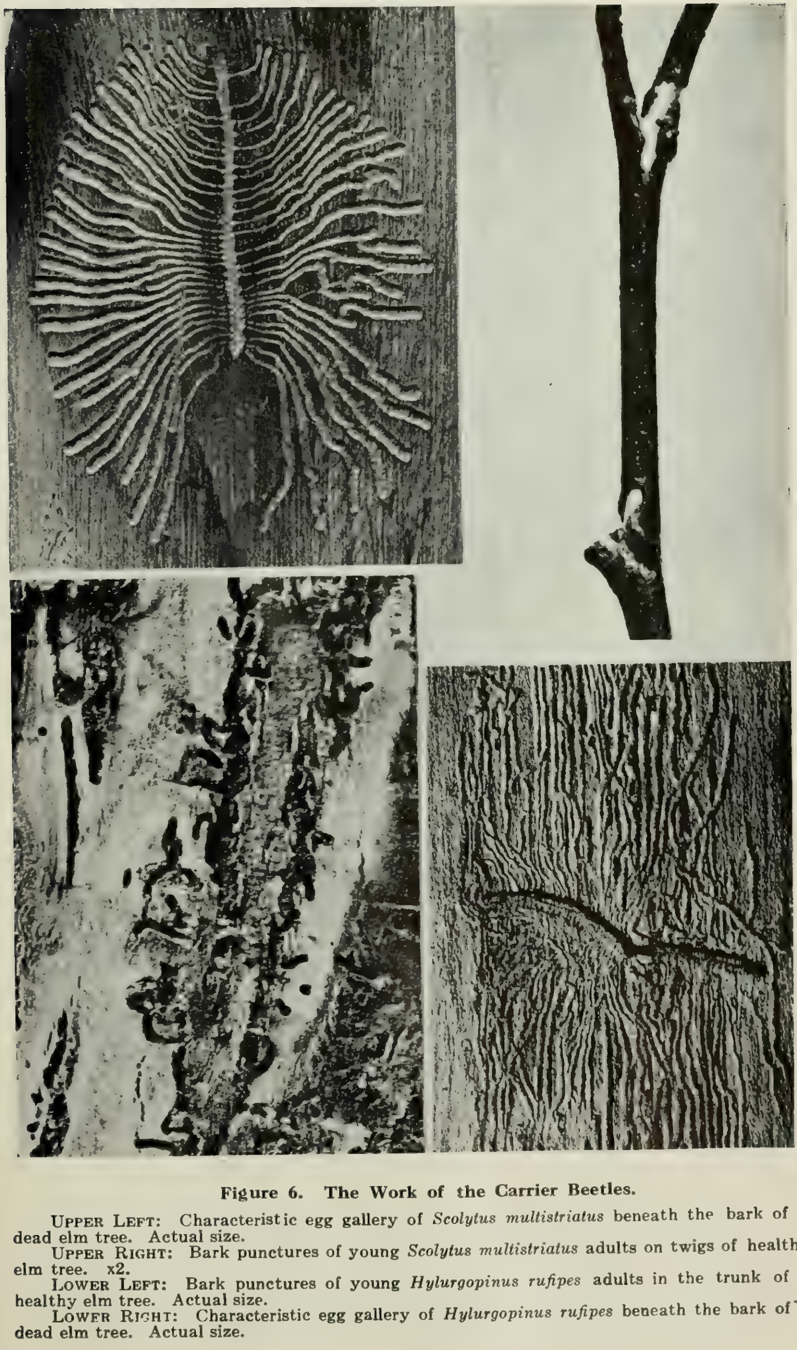


Figure 6. The Work of the Carrier Beetles.

Upper Left: Characteristic egg gallery of *Scolytus multistriatus* beneath the bark of a dead elm tree. Actual size.

Upper Right: Bark punctures of young *Scolytus multistriatus* adults on twigs of healthy elm tree. x2.

Lower Left: Bark punctures of young *Hylurgopinus rufipes* adults in the trunk of a healthy elm tree. Actual size.

Lower Right: Characteristic egg gallery of *Hylurgopinus rufipes* beneath the bark of a dead elm tree. Actual size.

bodies of migrating beetles. As these mites crawl about the elm bark, they may be instrumental in local spreading of the fungus over the tree.

Trees weakened by drought, leaf-infesting fungi or insects, or other causes, may become the breeding places of fungus laden beetles, and thus contract the disease. Such trees will, in turn, attract more carrier beetles.

The number of generations produced by the beetle in a season varies with the climate. In warmer regions, there may be two or more generations annually; in cooler regions, only one and perhaps a partial second. The number of generations produced in a given area may be influenced by variation in environmental factors. In that case, there would be an overlapping of generations, and beetles would be emerging throughout the warmer seasons of the year instead of all appearing at approximately the same time.

It is apparent that the life history of this beetle constitutes a vicious cycle, which produces a larger number of diseased trees each succeeding year, if it is not checked.

The Native Elm Bark Beetle

(*Hylurgopinus rufipes*)

It has been shown in experiments that this beetle also can transmit the Dutch elm disease fungus to elm wood and cause trees to become infected. To what extent this occurs in nature is not definitely known. The habits of this beetle are very similar to those of *Scolytus multistriatus.* It breeds in elm logs and dead or weakened elm trees. Young adults usually dig short tunnels into the bark on the trunks and branches of healthy elms before attacking elm logs and dead or weakened elm trees for breeding (Figure 6, lower left).

In central Massachusetts, this beetle has one complete generation and a partial second. Farther south it may have two. It is far more widely distributed than the introduced *Scolytus multistriatus.* It is present in all parts of Massachusetts and has been found throughout most of the range of the American elm.

The beetle is about the same size as *Scolytus multistriatus*, but differs from it in that it has a dull, uniform, dark brown color (Figure 5, B). Its egg gallery is dug more or less across the grain, and is two-branched, instead of being a single straight tunnel parallel to the grain (Figure 6, lower right).

Some Suspected Insect Vectors

Some other insects which bore in elm trees may prove to be carriers. At present, however, they are not known to be of any consequence.

One of these is the elm borer, *Saperda tridentata* Oliv. This is a beetle about one-half inch long, colored gray with red stripes. The larva is nearly an inch in length. It makes a long winding tunnel beneath the bark. The adult usually feeds on elm leaves before laying eggs in a shallow puncture in the bark.

Two closely related beetles known as the elm snout beetles, *Magdalis barbita* Say., and *Magdalis armicollis* Say., which have habits somewhat similar to *Saperda tridentata* Oliv., are also regarded with suspicion. The adults of of these two beetles are black and brown respectively and are about one-fourth of an inch long. The larvae or grubs resemble those of *Scolytus multistriatus.*

The buffalo tree hopper, *Ceresa bubalus* Fabr., and several other insects which attack elms are likewise suspected of being possible vectors.

CONTROL PRACTICES

At present, the introduction of diseased elm trees or burl-elm logs into the United States is prevented by federal quarantines. Within the United States, local quarantines have been established to limit further the transit of the Dutch elm disease beyond the boundaries of areas having infested trees.

Measures to control the Dutch elm disease in the regions of the United States where the disease is known to occur are directed toward preserving healthy trees by the careful, prompt, and thorough eradication of all elms known to be infected, and a supplementary sanitation program.[1] Whether or not elms are located in an area where they are exposed directly to the Dutch elm disease, it is a good practice to keep them in a healthy condition and free from dead branches in which beetles might breed. However, there is no complete assurance that an elm which is relatively healthy will not be affected by the disease, since experience has shown that the "average elm" is susceptible.

In Europe, no general eradication program has been carried out and attempts to control the disease by occasionally destroying affected trees in various places have failed to show any constructive results. In the United States, persons charged with the responsibility for the federal control program have expressed the encouraging opinion that eradication of the disease in this country is an attainable goal. But no program except a planned and sustained campaign against the disease can possibly achieve success in the eradication or even the practical control of the Dutch elm disease.

Reports on the introduction of zinc chloride and copper sulfate into the sap stream as a means of impregnating and poisoning against further attack by fungi and insects indicate that a means is at hand for destroying organisms in "doomed trees" whenever the actual removal of the trees must be delayed for any reason. However, only trees which are definitely scheduled for destruction should be treated by this process since *treated trees are certain to die.* Moreover, it must be borne in mind that as yet the practice of the distribution of poisons by the sap stream in elms cannot be transferred to industry in the place of pressure processes used on felled trees for the preservation of heavy service woods.

THE FUTURE OF ELMS IN MASSACHUSETTS

At the present time the Dutch elm disease is not known to occur in Massachusetts. However, the oldest known American infestation of the principal carrier insect of the disease, the smaller European elm bark beetle, was discovered in the vicinity of Boston in 1909. With this known carrier already well established in Massachusetts, the elms of the State would be in grave danger of destruction should the Dutch elm disease be introduced among them. It is, therefore, most important that prompt discovery be made of the first cases of the disease that may occur in Massachusetts in order that immediate steps may be taken to eliminate all sources of infection. Every one is urged to cooperate in the effort to protect and preserve the elm trees of the State for future generations.

---

[1] In one area where diseased and beetle-infested trees were not destroyed until most of the beetles had emerged, the diseased trees found the following year were much more numerous than those found in a similar area where the affected trees were destroyed soon after their discovery and before the beetles had emerged to any appreciable extent.

An Elm Blossoming in the Spring.

The Dutch elm disease threatens destruction of the American elm. The only hope of saving Massachusetts elms lies in early discovery and prompt destruction of the first infected trees found in the State. Watch for dying branches; wilting and yellowing leaves on terminal twigs; premature leaf-fall; brown streaks or spots showing in outer wood rings and under the bark of sections cut from wilt-affected branches. If these signs appear, cut six-inch sections of half-inch diseased twigs; label with the location of the tree and your name and address; wrap securely; and send to —

THE SHADE TREE DISEASE LABORATORY,
MASSACHUSETTS STATE COLLEGE,
AMHERST, MASSACHUSETTS.

Publication of this Document Approved by Commission on Administration and Finance
6m-5'37. No. 887.

140
344

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 344 July, 1937

Agri. Library
File No. 3

Inheritance of Egg Size and Egg Character

By F. A. Hays

A study of egg size and egg character, covering nine generations of Rhode Island Reds, is summarized in this report. The data furnish more definite information on the inheritance of egg size, egg shape, shell texture, shell porosity, and shell color; thus making it possible to offer some specific recommendations to poultry breeders.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

CONTENTS

Introduction 3
  Objects of investigation 5
  Data available 5

Part I. Egg Weight
  A. Winter egg weight 6
    Correlation between winter and hatching-season egg weights . 6
    Correlation between winter and annual egg weights . . . 8
  B. Hatching-season egg weight 8
    Correlation between hatching-season and annual egg weights . 8
    Hatching-season egg weights of parents and daughters . . 8
  C. Annual egg weight 10
    Monthly mean egg weights 10
    Progress in breeding for egg size 12
  D. Time to standard egg weight 13
    Breeding value of fast, medium, and slow dams . . . 14
  E. The inheritance of egg weight 15
    Fixing large egg size in the flock 17
Part II. External egg characters
  A. Shell texture 18
    Inheritance of shell texture 19
  B. Character of the ends of eggs 20
  C. Shell porosity 21
  D. Egg shape 22
  E. Egg shell color 23
    Shell flecking 23
    Shades of egg shell color 23
Summary 26
References 27

INHERITANCE OF EGG SIZE AND EGG CHARACTER

By F. A. Hays, Research Professor of Poultry Husbandry

INTRODUCTION

Egg size and external egg character studies involve a considerable number of problems that have been considered by many investigators. Curtis (1914) studied egg weight in 22 Barred Rock females during the first two laying years. During the first year there was an increase in egg weight up to April and a new high level appeared in September. Hadley and Caldwell (1920) reported on 38 White Plymouth Rock females. In these birds egg weight reached the highest level of the pullet laying year during April and attained a new high level the following December. Atwood (1923) pointed out that the mean egg weight of White Leghorns not bred specifically for high egg production increased each month of the first laying year. Jull (1924a) reported the mean monthly egg weights on 40 Barred Rock females during their first laying year. Maximum egg weight occurred in February and a new high level in egg weight appeared the following November. Jull (1924b) further showed that egg weight was intimately related to production and that the time when laying began had a very significant effect on egg weight. Hays (1930) presented data on 222 Rhode Island Red pullets, also observing maximum egg weight during February and a rapid increase in egg weight during September at the end of the laying year.

The data of all of the above workers stress the fluctuations in egg weight from month to month in the first laying year and indicate that caution is needed in classifying birds for egg weight when weighings are made only a few times during the year.

Commercially an individual egg weight of 56.7 grams or 24 ounces to the dozen is considered standard. It is probable also that a mean egg weight of 56.7 grams for all the eggs laid during the first laying year is a satisfactory goal for poultrymen to attain especially in flocks bred for high fecundity.

A number of workers have studied the relation of the weight of the first pullet eggs to mean annual egg weight in order to obtain a physical basis for selecting laying pullets at the beginning of the year. Maw and Maw (1932) reported that White Leghorn pullets whose first ten eggs averaged less than 47.5 grams each were not likely to attain standard egg weight the first year. The mean weight of the first ten eggs laid by these pullets in the fifth laying month corresponded closely to the mean egg weight for the entire year. Jull and Godfrey (1933) found that White Leghorns that will show a mean annual egg weight of 56.7 grams must have an average weight of the first ten eggs between 48.86 and 50.00 grams. Wilson and Warren (1934) presented data on White Leghorns, Rhode Island Reds and Barred Plymouth Rocks. These workers found that pullets starting with an egg weight of less than 46 grams in October, 50 grams in November, or 52 grams in December or later generally failed to attain standard egg weight the first year. Hays (1929) reported that Rhode Island Red pullets must lay 52-gram eggs in November and 55-gram eggs in December if they are to lay standard weight eggs by March 1.

The behavior of egg weight after the first year is of considerable importance to the breeder as well as economically. Hadley and Caldwell (1920) reported maximum egg weight during the second laying year with a gradual decline in later years. Atwood (1926) noted that White Leghorns almost attained maximum egg size in the second laying year. Hays (1929) showed that Rhode Island Reds reached maximum egg weight in the second year. In general there is not likely to be much change in egg weight after the second laying year. On the average, the egg weight of the second year will range from 7 to 10 percent greater than during the first year.

A considerable group of factors are known to affect egg weight. A number of workers including Parkhurst (1933) have shown that deficient or inadequate rations tend to reduce egg size. Parkhurst reported the following factors as partly responsible for reduced egg size: Lack of vitamin D, grain and mash as compared with an all-mash ration, lack of green food and oyster shell, and the substitution of either soybean or meat meal for fish meal. Bennion and Warren (1933) showed that temperatures above 85 degrees reduced egg size from 15 to 20 percent.

A number of inherited characters are known to affect egg weight. Among the most important of these is body weight, according to the work of Atwood, Jull, Robertson, Pearl, Funk and Kempster and others. Age at sexual maturity also greatly affects egg weight according to Atwood, Jull, Funk and Kempster, Hays, and others. Intensity significantly affects egg size according to studies of Atwood, Funk and Kempster and Hays. Broodiness probably reduces egg size according to Hays (1934). High persistency increased egg size in Hays' (1934) studies.

There are probably several Mendelian factors that directly control egg size. Small egg size was found to be dominant by Benjamin (1920), Hurst (1921), Kopec (1924), and Hays (1929). Waters and Weldin (1929), on the other hand, suggested that large egg size may be dominant.

Egg shape and shell texture have been very little studied from the genetic standpoint. Both Benjamin (1920) and Kopec (1924) have stated that egg shape is inherited, but no genetic analysis was reported. Shell texture has been studied largely from the nutrition standpoint and in its relation to hatchability. There are no reports concerning the behavior of shell texture in inheritance.

The mode of inheritance of shell color has been studied by a number of workers. Hurst (1905) and Benjamin (1920) obtained an intermediate color in F_1 by crossing brown-shelled and white-shelled breeds of fowl. Punnett and Bailey (1920) believe that there is a major gene for brown shell color and several minor genes. Intermediate shades depend on the presence of one or more minor genes and white color upon the absence of major and minor genes. Kopec (1927) reported that shell color depends upon several factors, each of equal importance. In general it is probable that egg-shell color depends on multiple factors and that first-generation crosses between brown and white races would be expected to give intermediate shell color.

Objects of This Investigation

In planning this experiment several definite objects were kept constantly in mind, the most important of which are the following:

1. A determination of the possible genetic factors that act directly on egg size up to January first, during the normal breeding season, and through the entire first laying year.
2. Genetic factors affecting external shell texture.
3. Possible genes governing the shell character of the ends of the eggs.
4. Genetic factors affecting the porosity of the egg shell.
5. A genetic analysis of egg-shell color inheritance.
6. Determination of possible genetic factors governing egg shape.

Data Available

Three lines were established during the hatching season of 1928 and carried through nine generations, the last being hatched in the spring of 1936. Data on egg weight for the last generation were completed only through the hatching season.

Line A was a small-egg line from pullet mothers. The first three generations were produced by mothers with a mean December egg weight of 52 grams (22 ounces to the dozen). The fourth generation was from mothers selected from the three different lines on the basis of a December egg weight of 52 grams. To produce the fifth and sixth generations, mothers of line A were selected with a 52-gram egg weight in November. Generations seven, eight, and nine were from mothers selected on the ability to attain an egg weight of 56.7 grams between 61 and 90 days after the first pullet egg. Generation four was the only generation produced by some mothers outside of line A.

Line B was developed for medium egg size. The first three generations of pullet mothers were selected on the basis of a mean December egg weight of 57 grams (24.1 ounces to the dozen). The fourth generation was from pullet mothers from the three different lines selected on the basis of a December egg weight of 57 grams. The fifth and sixth generations were produced from pullet mothers of line B laying 57-gram eggs in November. Generations seven, eight, and nine were from pullet mothers showing a mean egg weight of 56.7 grams between 31 and 60 days from first egg. The fourth generation alone was produced from females outside of line B.

Line C was considered a large-egg line. The basis for selecting the mothers to produce the first three generations was a mean December egg weight of 59 grams (25 ounces to the dozen). The fourth generation was from pullet mothers from the three different lines showing the ability to lay 59-gram eggs in December. The fifth and sixth generations were from pullet mothers of line C laying 59-gram eggs in November. Generations seven, eight, and nine were out of mothers laying 56.7-gram eggs within 30 days after the first egg. Only generation four came in part from mothers outside of line C.

The males siring each generation were cockerels. Three full brothers were chosen, one to head each line each year. In order to avoid close breeding these males were taken from another experiment. An effort was made each year to secure males with large-egg ancestry. The object in using full brothers throughout the experiment was to retain the greatest possible uniformity in the male ancestry.

The first five generations were hatched in eight weekly hatches from March 25 to May 15, and the last four generations three weeks earlier.

PART I. EGG WEIGHT

A. Winter Egg Weight

Winter egg weight as used in these studies is the mean of all eggs laid from the first pullet egg to January first of the first laying year. Such information is valuable particularly in the selection of pullets for breeding purposes. The three lines of birds will be considered separately in this report.

Chart 1 indicates the general trend with respect to winter egg weight in the three lines. The mean winter egg weight showed a gradual upward trend throughout the experimental period in all three lines, which was much more pronounced in lines B and C. From 1930 to 1935 the daughters in line A had a heavier mean egg weight than their dams. This fact suggests that the sires of these daughters must have transmitted greater egg size than the dams. On the other hand, in lines B and C the daughters for the most part fell below their dams in egg size. It is probable that the inheritance for egg size of the sires used was not equal to that of the dams. The data show a general parallelism in egg weight between mothers and daughters.

The mean egg weight of all the daughters to January first was as follows:

Line A, 52.23 ± .143 grams (22.1 ounces to the dozen)
Line B, 53.81 ± .168 grams (22.8 ounces to the dozen)
Line C, 53.85 ± .169 grams (22.8 ounces to the dozen)

The difference between the means for lines A and B was 1.58 ± .221 grams, which is definitely significant. The difference between the means for lines B and C was .04 ± .238 grams, which is insignificant. Evidently the plan of breeding followed was effective in producing heavier egg weight in line B than in line A, but not effective in producing greater egg weight in line C than in line B.

Correlation between Winter Egg Weight and Hatching-Season Egg Weight by Lines

For market purposes and in the production of eggs to be used for hatching later in the season, certain weights are desirable. Information relative to the association between egg weight up to January 1 and egg weight in February or March following should be helpful to the breeder.

The populations in the three lines were tested for normalcy in winter egg weight. In all three lines the probability of a normal sample was very high. The X^2 test for normalcy in hatching-season egg weight also showed all three lines to be satisfactory samples.

The regression of hatching-season egg weight on egg weight to January 1 was strictly linear in all three lines. The coefficients of correlation were as follows:

Line A, + .7211 ± .0211
Line B, + .8131 ± .0141
Line C, + .8556 ± .0118

These are very significant constants and indicate that about 65 percent of the variation in hatching-season egg weight is associated with variation up to January 1. The data show further, from the regression coefficient, that on the average pullets that lay 53-gram eggs (22.5 ounces to the dozen) up to January 1 may be expected to lay 56.7-gram eggs (24 ounces to the dozen) in February and March.

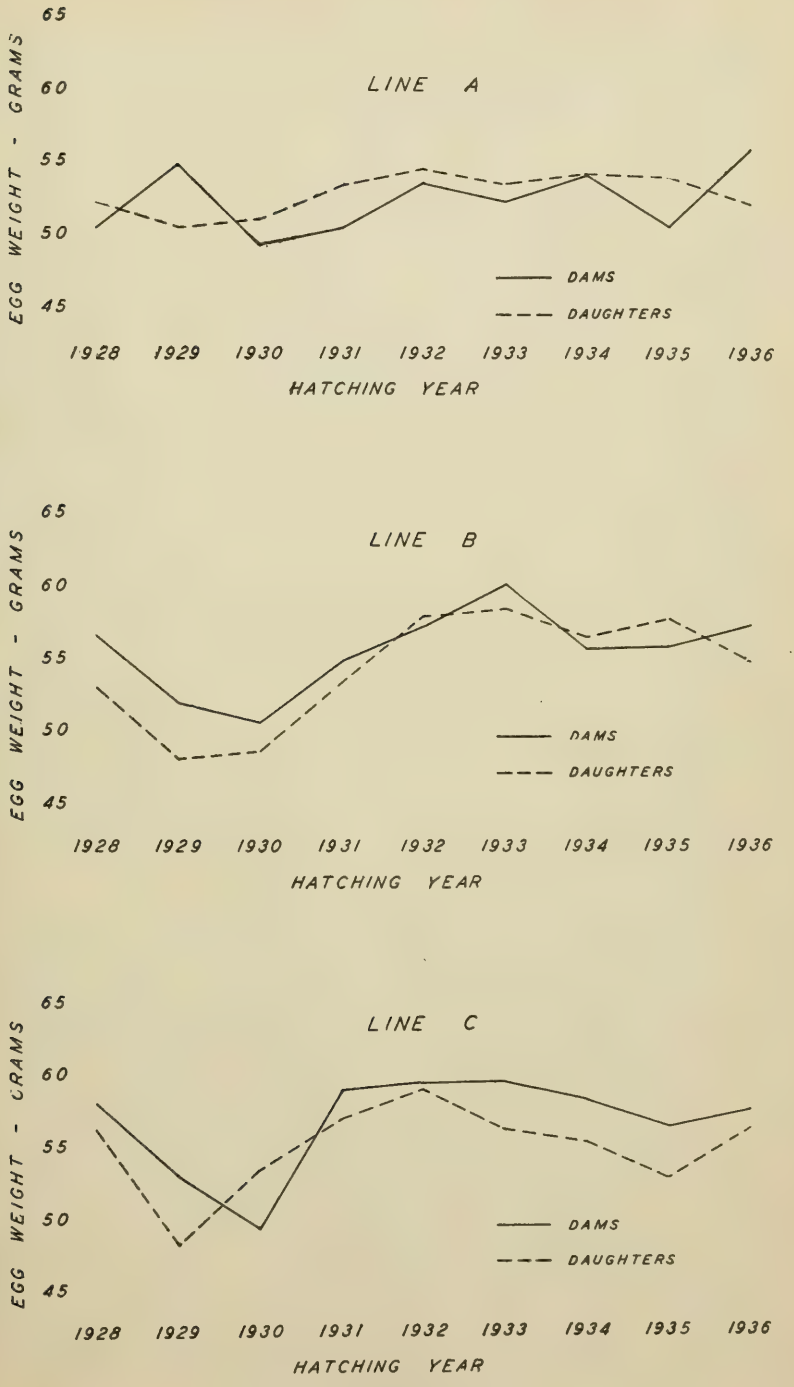


Chart 1. Winter Egg Weight.

Correlation Between Winter Egg Weight and Annual Egg Weight, by Lines

Regression of annual egg weight on winter egg weight was strictly linear. The coefficients of correlation were as follows:

Line A, + .8495 ± .0162
Line B, + .8823 ± .0125
Line C, + .8775 ± .0133

These constants indicate that more than 75 percent of the variation in annual egg weight is associated with variation up to January 1. Birds that are to average 56.7-gram eggs (24 ounces to the dozen) for the year should lay 54-gram eggs (23 ounces to the dozen) up to January 1.

B. Studies on Hatching-Season Egg Weight

Hatching-season egg weight was determined during February and March of the pullet year. At this time the birds had been laying for about five months and were between ten and eleven months old. According to previous data (Hays, 1910), maximum egg weight for the pullet year occurs in February. A study of egg weight during this period should furnish valuable information to the breeder.

Correlation Between Hatching-Season Egg Weight and Annual Egg Weight, by Lines

Regression of annual egg weight on hatching-season egg weight was linear. The coefficients of correlation were as follows:

Line A, + .9111 ± .0104
Line B, + .9261 ± .0088
Line C, + .8004 ± .0225

These constants show that more than 77 percent of the variation in annual egg weight is associated with variation in the hatching season. The regression constants further show that on the average the hatching-season egg weight of the pullet year must be about 58.2 grams (24.7 ounces to the dozen) if such birds are to average 56.7 grams (24 ounces to the dozen) for the full pullet laying year.

Hatching-Season Egg Weight of Parents and Daughters

There can be no specific method for measuring egg size in males, but a record of the egg size of their full sisters does throw some light on their possible genotype. Complete records are available on the dams used. Chart 2 illustrates graphically the hatching-season egg weight of sisters of sires, of dams, and of daughters in the three lines throughout the experiment. All egg weights were made during the pullet laying year.

The mean egg weight of the sisters of the sires used throughout the experiment shows a rather consistent increase as the experiment progressed. There is high probability that the sires during the last three years may have belonged to the large-egg phenotype. Evidently these brothers were not homozygous for genes B and C, because they did not breed true in any of the three lines.

The dams in line B apparently represent a fortunate selection as far as egg size is concerned. In contrast, the dams of line C were scarcely as good at the end of the experiment as at the beginning. Here is further evidence of the difficulties in developing the large-egg phenotype. If the large-egg phenotype did not depend on the cumulative action of genes B and C, there would have been less difficulty.

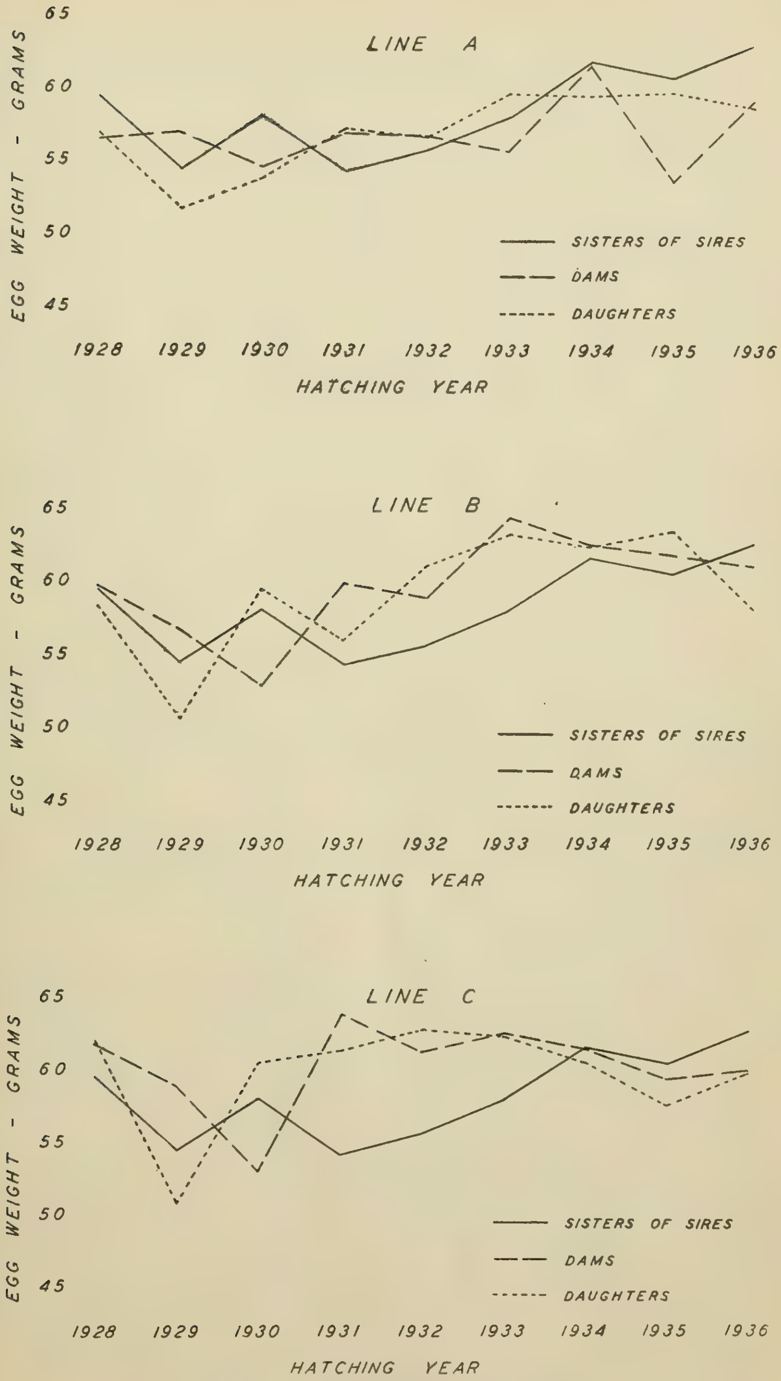


Chart 2. Hatching-Season Egg Weight.

Daughters in lines A and B showed an upward trend in egg size as the experiment continued. In line C there was no improvement in the last four generations. The daughters of line C did not increase, because their dams were for the most part of the medium phenotype. In line B the generations of daughters hatched in 1934 and 1935 exhibited in a pronounced way the breeding ability of sires and dams that belong to the large-egg type. Line B affords a good illustration also of the breeding value of dams in the medium-egg-size group.

All of the daughters produced in the three lines were grouped in a frequency distribution and tested for normalcy of sample. The X^2 test for each of the three lines indicated them to be satisfactory samples for statistical study. The mean hatching-season egg weight was as follows:

Line A, 56.84 ± .182 grams (24.1 ounces to the dozen)
Line B, 58.78 ± .205 grams (24.9 ounces to the dozen)
Line C, 58.92 ± .211 grams (25 ounces to the dozen)

The difference in mean egg weight of lines A and B was 1.94 ± .274 grams, which is a significant difference. The difference in means of lines B and C was .14 ± .294 grams, which is insignificant. These data agree with the observation on winter egg weight in section A. The fact is evident in this experiment that the method of selective breeding used did produce a significant difference in hatching-season egg weight between lines A and B, but not between lines B and C.

C. Studies on Annual Egg Weight

Annual egg weights used here represent the mean of twelve monthly averages, beginning with October of the pullet year and ending the following September. Every egg was weighed to the nearest gram when taken from the trapnest. The data are handled separately for the three lines.

Mean Monthly Egg Weight by Lines

Table 1 presents the mean monthly egg weights for the three lines, including the last five generations. Complete data on the generations hatched in 1928, 1929, and 1930 are not available.

TABLE 1. — MEAN MONTHLY EGG WEIGHT BY LINES, 1931–1935

Line	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Yearly Mean
A	50.7	53.1	55.4	57.0	58.2	58.4	58.1	57.5	57.7	57.3	57.7	58.4	56.15
B	54.3	56.8	58.9	60.5	62.0	62.3	61.2	60.5	60.2	59.3	59.7	60.2	58.30
C	51.9	54.3	56.5	58.2	59.7	60.0	59.0	58.0	58.2	57.3	58.0	58.9	57.03

Line A is represented by 122 birds, line B by 120 birds, and line C by 106 birds with complete annual egg-weight records. The table shows that maximum egg weight occurred in March in all three lines. It should be noted that the September egg weight of line A was as high as the March weight. These data point to the maximum egg weight of the pullet year occurring during the sixth laying month, preceded by a rather consistent rise from the first pullet egg and followed by a decline in April and May. During June, egg size began to recover and during September it approached the March level.

Mean yearly egg weights were calculated by taking the average of the sum of the individual yearly weights, and were as follows:

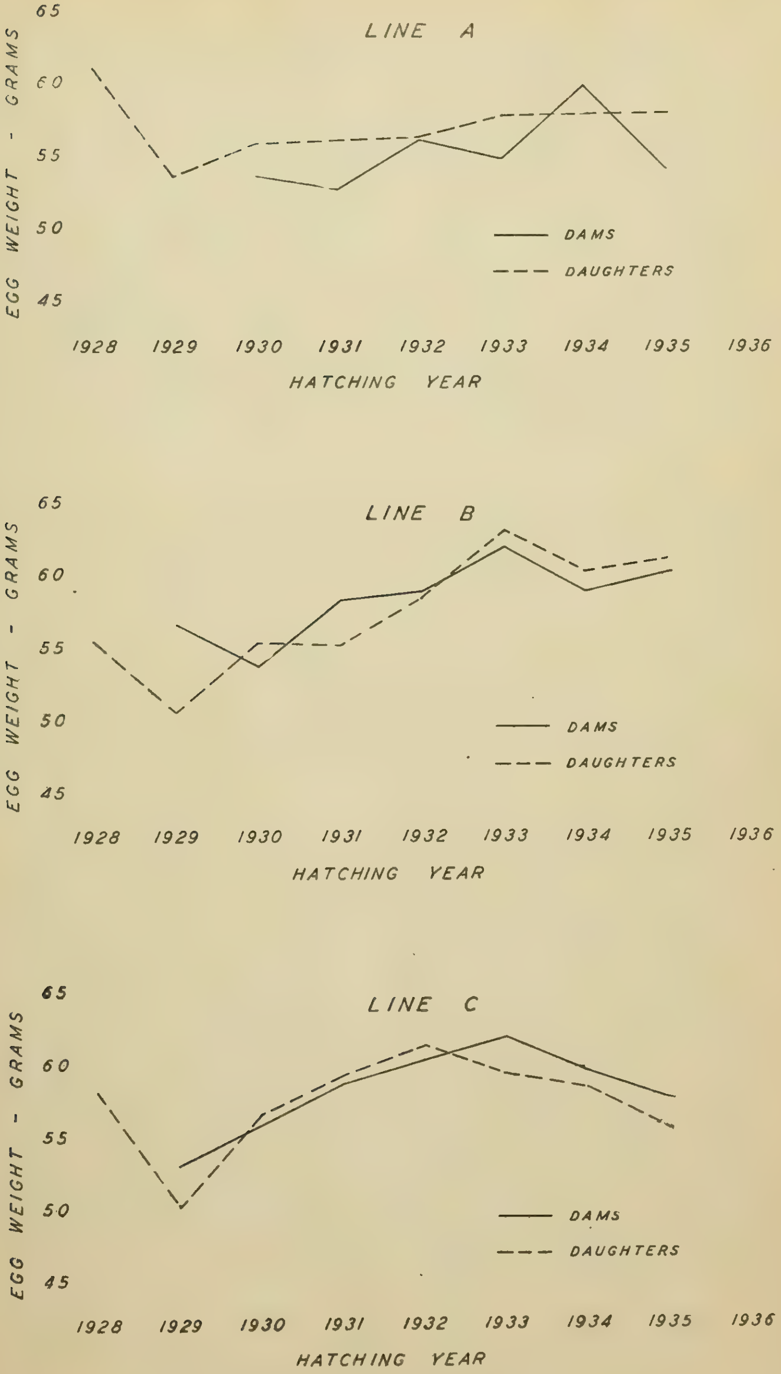


Chart 3. Annual Egg Weight.

Line A, 56.15 ± .205 grams (23.8 ounces to the dozen)
Line B, 58.30 ± .247 grams (24.7 ounces to the dozen)
Line C, 57.03 ± .235 grams (24.2 ounces to the dozen)

The data show in general that eggs laid during the month of maximum weight average about 4 percent heavier than the mean for the pullet year. The birds in line A did not average standard egg weight until January; those in line B averaged standard egg weight in November, and those in line C sometime in December. Each line was checked for normalcy of sample by the X^2 test and all gave a high probability of normalcy, the lowest probability being .6314. The differences in the means may be checked against the probable error of difference. Line B had a mean annual egg weight 2.15 ± .321 grams greater than line A. This is a statistically significant difference. The difference between lines A and C was .88 ± .312 gram, and is of doubtful significance. Line B had an annual egg weight 1.27 ± .341 grams heavier than line C. Here is a significant difference in the reverse order of expectation. These results may be partially explained on the basis of female ancestry, as shown on Chart 3.

Progress in Breeding for Egg Size

Annual egg records of mothers and daughters are summarized in Chart 3, which presents in graphic fashion the mean annual egg records of mothers used to produce daughters in each year in the experiment.

In line A there was a rather consistent increase in egg weight of daughters as the experiment continued. Dams for breeding in 1934 and 1935 were selected on the basis of time to standard egg weight rather than upon a particular egg weight basis. These dams ranged from 61 to 90 days in time required. A superior group of dams resulted in 1934 but the 1935 dams showed inferior annual egg weight. Complete annual egg weight records are not available on the first two generations of dams and only part of their daughters had egg weight records throughout the year.

There was a remarkably consistent increase in mean annual egg weight in both mothers and daughters of line B through eight generations. The last two generations of mothers reached standard egg weight in 31 to 60 days. In annual egg weight these mothers fell below the previous generation of mothers that were selected on the basis of 57-gram eggs in November. The last two generations of daughters paralleled these dams in annual egg weight.

Line C dams showed an increasing annual egg weight for five generations. When the basis for selecting dams in this line was changed in 1934 to those reaching standard egg weight in 0 to 30 days there was a decline. The daughters in this line began to decline in 1933 when their dams were chosen on the basis of 59-gram eggs in November. The general behavior of line C suggests the epistatic nature of a gene for small egg size combined with chance selection of males transmitting small egg size in this line. The data indicate further that there is no advantage from the standpoint of annual egg weight in selecting breeding females laying heavier than 24-ounce eggs in November if they are to be used for breeding in March and April.

D. Time to Standard Egg Weight

The time required from first pullet egg to a standard egg weight of 56.7 grams (24 ounces to the dozen) was recorded throughout the experiment. Table 2 summarizes the results with reference to the percentages of birds in the three lines that actually attained this standard egg weight during their first laying year, and the mean time required. Complete data are not available on the first three generations.

TABLE 2. — PERCENTAGE OF DAUGHTERS REACHING STANDARD EGG WEIGHT AND MEAN TIME REQUIRED

YEAR Hatched	LINE A		LINE B		LINE C	
	Percentage Qualifying	Mean Days	Percentage Qualifying	Mean Days	Percentage Qualifying	Mean Days
1928 . .		47.4		55.3		33.9
1929 . .		69.9		23.4		
1930 . .		84.3		90.3		58.4
1931 . .	81.0	79.2	74.1	64.2	100.0	31.2
1932 . .	92.6	60.5	95.5	21.4	100.0	18.1
1933 . .	91.2	75.4	100.0	28.8	100.0	59.8
1934 . .	95.5	71.4	100.0	45.4	100.0	58.0
1935 . .	100.0	87.1	100.0	32.0	80.8	97.5

Lines A and B behaved in a similar way throughout the experiment with respect to the percentages of birds attaining standard egg weight. In these two lines there was a consistent increase in percentages of qualifying birds from year to year. Line C was inconsistent in the last generation. It is probable that gene A was carried by a considerable number of individuals in line C in the last generation.

Mean days required to reach standard egg weight did not behave in the same way in the three lines. Line A showed an increase in mean time to standard egg weight as the experiment progressed; Line B showed a decrease in average time required; while line C showed a significant increase in the last three generations. The fact becomes evident from these data, in comparison with data on egg weight during the hatching season, that egg weight in the normal hatching season does parallel the time required to reach standard egg weight. In other words, individuals that are slow in attaining a 24-ounce egg weight are more likely to produce smaller eggs for hatching.

Frequency distributions were made for the qualifying birds in the three lines on the basis of time to standard egg weight. No line gave a normal variability curve. Line A showed the closest approach to a normal curve, but was definitely not normal. This fact shows that time to standard egg weight is not a simple fluctuating character, but is governed by a series of characters. If the time to standard egg weight were governed by two or three heritable genes, bimodal or trimodal frequency graphs would appear. There was no evidence of such a simple situation in these data. The mean time to standard egg weight for all daughters qualifying in the three lines during the experiment was as follows: line A 69.9 days, line B 42.8 days, and line C 52.3 days. Since these data do not represent a normal frequency distribution, the probable error of the mean could not be calculated.

For purposes of comparison all the daughters in the three lines have been divided into three groups with respect to time to standard egg weight. Those attaining standard egg weight in from 0 to 30 days are fast; those requiring 31 to 60 days, medium; and those requiring 61 days or longer, slow. Table 3 shows the summarized results of this classification.

TABLE 3. — ALL DAUGHTERS CLASSIFIED ACCORDING TO TIME REQUIRED TO ATTAIN STANDARD EGG WEIGHT

	Line A	Line B	Line C
Fast	38	89	74
Medium	33	45	40
Slow	90	49	79

The data indicate that line A daughters fell predominantly in the slow class. Line B showed about half the daughters to be fast, with one fourth medium and one fourth slow. Line C had equal numbers of fast and slow, and about half as many in the medium class. The fact that line C carried so many birds in the slow class is a further indication of the occurrence of small-egg genes in this group. The fact should be kept in mind, however, that this classification includes only daughters that did attain standard egg weight. The following study on the character of daughters produced by fast, medium, and slow dams will throw some light on their relative value for breeding.

Breeding Value of Fast, Medium, and Slow Dams

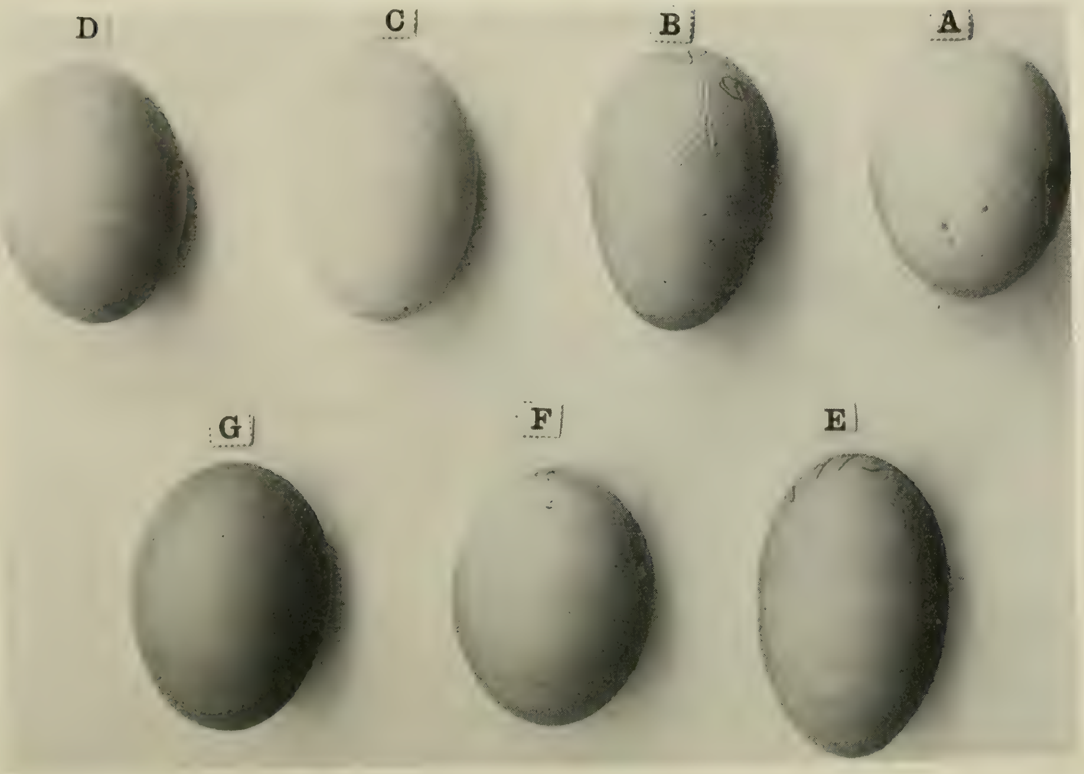
Records on time required to standard egg weight are available on only part of the dams and daughters. Available data are summarized in Table 4, and may be assumed to approximate the true situation.

Fast dams were used for breeding in lines B and C. In Line B these dams produced fast, medium, and slow daughters in the proportions of about 2–1–1. In line C fast dams gave the three classes of daughters in the proportions of about 2–1–2. Medium dams were used in all three lines. In line A, the three types of daughters occurred in proportions of about 1–1–1.5.

Line B daughters from medium dams occurred in approximately 2.5–1–1 proportions. In line C the medium dams gave daughters in about 2–1–1.5 proportions. Slow dams in line A gave daughters in about the ratio of 1.5–1–3. In line B the ratio of the different kinds of daughters was about 1–1–1. Only one dam of the slow class occurred in line C. This dam gave only slow daughters. There were three dams that did not attain standard egg weight during the first year. These were all in line A and gave the three kinds of daughters in proportions of about 1–2–5.

A general survey of the breeding results from the three classes of dams with respect to time to standard egg weight shows that the time required depends on inheritance. There is a general parallelism between time required to attain standard egg weight and egg size. The data are suggestive of more than one dominant gene operating to reduce the time interval and possibly of an epistatic gene lengthening the time to standard egg weight. The selection of females for breeding purposes should be made on the basis of ability to lay standard-weight eggs within sixty days from the first pullet egg.

Plate 1. Shell Texture and Egg Shape.



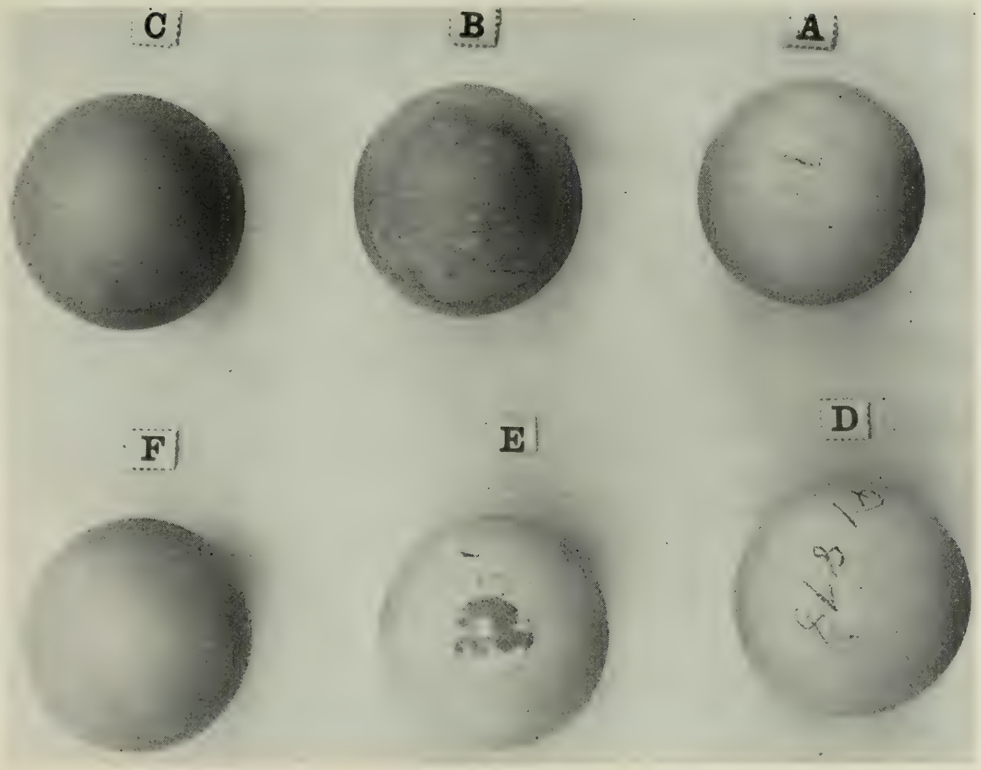
Texture

D. normal
C. sandy
B. ridged
A. rough

Shape

G. normal
F. round
E. long

Plate 2. Character of Tips and Butts



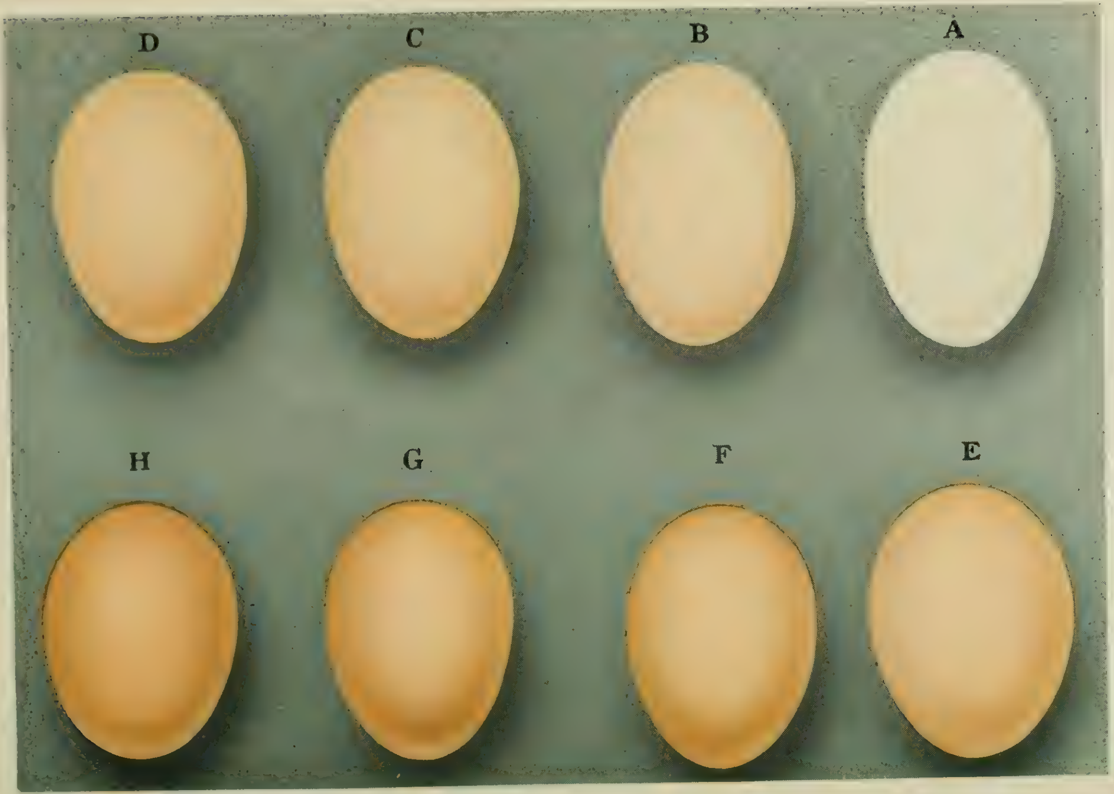
Tips

C. normal
B. thin
A. sandy

Butts

F. normal
E. thin
D. sandy

Plate 3. Shades of Shell Color.



A. white
B. pale pinkish buff
C. pale pinkish cinnamon
D. pale cinnamon pink

E. pinkish buff
F. light pinkish cinnamon
G. light vinaceous cinnamon
H. vinaceous cinnamon

TABLE 4. — BREEDING VALUE OF DAMS, FAST, MEDIUM, AND SLOW OR FAILING TO REACH STANDARD EGG WEIGHT

Dams Classified by Time to Standard Egg Weight	Number of Dams	Daughters Classified by Time to Standard Egg Weight		
		Fast	Medium	Slow
Fast				
Line A	0	–	–	–
Line B	7	19	8	7
Line C	10	37	16	37
Medium				
Line A	2	4	3	6
Line B	12	60	24	26
Line C	6	34	16	22
Slow				
Line A	10	27	19	56
Line B	4	9	11	10
Line C	1	–	–	6
Failing				
Line A	3	3	6	16
Line B	0	–	–	–
Line C	0	–	–	–

E. The Inheritance of Egg Weight

In previous sections egg weight has been considered during the winter period, during the normal hatching season, and for the entire first laying year. As indicated in section B, hatching-season egg weight is a close approximation to the maximum egg weight of the first laying year. This maximum egg weight offers a convenient basis for the study of genes concerned in the inheritance of egg weight. The terms size and weight are used interchangeably in this report.

In a previous report from this Station Hays (1929) suggested that two dominant genes primarily affect egg size. Gene B was indicated as a dominant producing eggs weighing 56.7 grams (2-ounce eggs) or more. Gene A is also a dominant producing eggs weighing under two ounces in the hatching season. This latter gene is epistatic to gene B and with it gives an intermediate egg size, but below 56.7 grams. In these earlier studies large eggs (63 grams or heavier) were not common. In recent years, by selective breeding, egg size has been built up so that many individuals now lay eggs weighing 63 grams or more. In the experiment being reported, results with egg weight require a modification of the AB theory.

An examination of the frequency distribution for egg weight during the hatching season suggests modal classes at about 55–56 grams (23.5 ounces to the dozen) and 61–62 grams (26 ounces to the dozen) as well as the large proportion falling near the 57-gram (24 ounces to the dozen) class. In studying the inheritance of egg weight, dams and daughters have been placed in three phenotypes. The large-egg type laid eggs weighing 63 grams (26.7 ounces to the dozen or more); the medium type ranged from 57 to 62.9 grams (24.2 to

26.6 ounces to the dozen); the small-egg type ranged from 56.9 grams (24.1 ounces to the dozen) downward during the hatching season. Minimum weight for the medium- and large-egg types has been placed high so as to prevent as far as possible overlapping with the upper extremes of the class below.

Table 5 gives the summarized breeding results from the three phenotypes of dams in each line through nine generations.

TABLE 5. HATCHING-SEASON EGG WEIGHT

Dams Classified by Hatching-Season Egg Weight	Number of Dams	Number of Daughters	Daughters Classified by Hatching-Season Egg Weight		
			Large	Medium	Small
Large					
Line A	1	13	3	8	2
Line B	5	42	15	18	9
Line C	6	41	15	24	2
Medium					
Line A	10	87	6	39	42
Line B	21	172	43	88	41
Line C	16	164	28	79	57
Small					
Line A	15	135	7	65	63
Line B	7	52	1	19	32
Line C	6	31	8	22	1

Large-egg dams produced about the same proportions of large, medium and small-egg daughters in lines B and C. The medium-egg dams of line A gave a lower percentage of large-egg daughters than occurred in either line B or line C. The most notable fact with the small-egg dams was the greater proportion of medium and large daughters in line C. This last observation indicates that the line-A dams were more likely to be homozygous for small-egg genes and further points to the epistatic nature of these small-egg genes. In the fourth generation, hatched in 1931, the dams came from the different lines and not exclusively from within each line. The daughters produced in this year in line A slightly excelled those in line B for egg weight. This instance again suggests that small-egg dams from lines B and C were less likely to be homozygous for small-egg genes than were the dams from line A.

The data show that small-egg daughters came almost entirely from medium- and small-egg mothers. The class of daughters laying large eggs were from all three types of dams but largely from medium- and large-egg dams. Large-egg daughters were produced in considerable numbers by medium dams, suggesting that the gene reducing egg size of the dams segregates from the gene for large size so that the large-egg phenotype of daughters appears. In nine generations the percentages of large- and small-egg daughters were as follows:

	Small-egg Daughters Percent	Large-egg Daughters Percent
Line A	45.5	6.8
Line B	30.8	22.2
Line C	25.4	21.6

These studies indicate that a gene C for large egg size exists and is responsible for eggs that weigh 63 grams (26.7 ounces to the dozen) or more, laid by pullets when about eleven months old. These data further confirm previous findings that a gene A for small eggs occurs and that gene B for medium egg weight also operates. The data point further to a third gene C for large eggs and indicate that gene A is epistatic to both B and C. The general status of egg weight inheritance may be summarized:

Gene A alone gives small egg size.
Genes A and B together give a hatching-season egg weight below 57 grams or small.
Gene B alone gives medium egg weight 57 to 62.9 grams.
Gene C alone probably gives medium also.
Gene C with B gives large egg size.
Gene C with A gives medium.
Gene C with A and B gives medium.

Fixing Large Egg Size in the Flock

In a flock that has been bred for high fecundity there may be wide variability in egg weight. Uniformly large eggs produced in large numbers are very desirable. When mean egg size is lower than desired it is an indication of the presence of gene A in a considerable number of the population. Selective breeding from parents of the medium or large phenotypes is effective in increasing egg size because gene A is lacking. The use for breeding of males and females of the large phenotype is not more effective in raising the mean egg size of the daughters than the use of breeders of the medium type because the chances of bringing genes B and C together are fewer than the chances of producing birds carrying either genes B or C alone. It is probable that birds carrying gene C alone fall into the medium phenotype in egg size and the large egg type appears to arise from the cumulative action of genes B and C.

Economically, extreme egg weight is not desirable. In the first place extremely large eggs do not hatch as well as eggs of medium size. In the second place, very large eggs are likely to have poorer shells. In the third place, large eggs produce more reproductive injuries. In the fourth place the market does not ordinarily pay a premium for very large eggs that are produced at greater expense. In view of these facts a maximum egg weight for the pullet year should be about 61 grams or 26 ounces to the dozen and for later years about 65 grams or 27.5 ounces to the dozen.

Part II. External Egg Characters

These studies include records made on eight generations in the three lines. As indicated in the previous section, lines A, B, and C were developed primarily on the basis of egg weight. Any classification of individual hens on the basis of external egg characters must be purely relative and must be based on apparent divergences from an assumed normal condition. Complete egg descriptions were taken on all mothers and daughters but no information is available on the possible inheritance of the sires used. Since full brothers were used as sires in all three lines, their genetic make-up should be somewhat similar.

A. Shell Texture

Eggs were classified in shell texture as rough, ridged, sandy, or normal. Eggs with irregular ridges on the surface may or may not show a sandy or harsh texture. Rough eggs exhibit mineral spots. Normal eggs have a smooth texture and are free from any conspicuous ridges or irregularities. For purposes of study, the daughters from the different types of mothers were classified with respect to the shell texture of their eggs.

In line A there were 5 mothers that characteristically laid ridged eggs with smooth shell texture. These dams produced 44 daughters, of which 5 laid ridged eggs, 18 sandy eggs, and 24 smooth eggs. In this last group, 3 birds laid ridged eggs with smooth shell texture, thus leaving 21 individuals, or 47.7 percent, that may be classified as normal for shell texture. There were 8 mothers whose eggs were classed as sandy. The 72 daughters were grouped as follows: 2 rough, 11 ridged, 22 sandy, and 38 smooth. Only one laid ridged eggs with smooth texture, leaving 37, or 51.3 percent, normal daughters. The 57 daughters of the 7 dams producing normal eggs were rated: 4 ridged, 9 sandy, and 48 smooth. Four daughters laid ridged eggs with smooth shell texture, leaving 44, or 77.2 percent, laying normal eggs.

In line B, 3 dams described as ridged-smooth in shell texture gave 18 daughters grouped as 1 ridged, 5 sandy, and 13 smooth. The one daughter classed as ridged had also smooth shell texture, leaving 12, or 66.7 percent, normal daughters. One dam laying ridged and sandy eggs gave 6 daughters, classed as 2 ridged, 2 sandy, and 3 smooth, of which only 2 were normal. The 9 dams laying sandy eggs had 59 daughters rated as 10 ridged, 20 sandy, and 32 smooth. Three daughters laid ridged eggs with smooth shell texture, leaving 29, or 49.2 percent, normal. The 13 dams rated as normal gave 90 daughters classed as 1 ridged, 7 sandy, and 82 smooth. There was no overlapping in classification, and the 82 normal daughters make up 91.1 percent of the total.

In line C, one dam classed as ridged-smooth in egg shell texture gave 12 daughters, 2 of which laid sandy eggs and 10 normal eggs. The 7 dams classed as ridged and sandy had 34 daughters grouped as 10 ridged, 7 sandy, and 27 smooth. There were 10 daughters producing ridged-smooth shells, leaving 17 or 50 percent that laid normal eggs. Two dams classed as sandy gave 34 daughters, grouped as 6 ridged, 9 sandy, and 21 smooth. Two of the smooth daughters laid ridged-smooth eggs leaving 19 or 55.9 percent normal. There were 14 dams that laid normal eggs giving 109 daughters, ranked 1 rough, 12 ridged, 22 sandy, and 83 smooth. Nine daughters produced ridged-smooth eggs leaving 74 or 67.9 normal daughters.

TABLE 6. — EGG-SHELL TEXTURE OF MOTHERS AND DAUGHTERS

Dams Classified by Egg Character	Number of Dams	Number of Daughters	Daughters Classified by Egg Character					
			Rough	Ridged	Sandy	Smooth	Normal	Percent Normal
Ridged and smooth								
Line A . . .	5	44	—	5	18	24	21	47.7
Line B .	3	18	—	1	5	13	12	66.7
Line C . . .	1	12	—	—	2	10	10	83.3
Ridged and sandy								
Line A . . .	0	—	—	—	—	—	—	—
Line B . . .	1	6	—	2	2	3	2	33.3
Line C . . .	7	34	—	10	7	27	17	50.0
Sandy								
Line A . . .	8	72	2	11	22	38	37	51.3
Line B . . .	9	59	—	10	20	32	29	49.2
Line C . . .	2	34	—	6	9	21	19	55.9
Normal								
Line A . . .	7	57	—	4	9	48	44	77.2
Line B . . .	13	90	—	1	7	82	82	91.1
Line C . . .	14	109	1	12	22	83	74	67.9

*The "number of daughters" is the total of the rough, ridged, sandy, and normal. As indicated in the text, those classed as "smooth" are made up of the "normal" and a part of the "ridged."

Inheritance of Shell Texture

Table 6 shows that dams laying ridged eggs with smooth surfaced shells did not transmit the ridged shell character to any greater extent than did the normal dams. Dams laying ridged and sandy eggs and dams laying sandy eggs also produced about the same proportion of daughters laying ridged eggs as dams laying either ridged-smooth or normal eggs. This fact would suggest that the ridged shell condition does not depend upon inheritance.

Dams laying eggs with sandy surfaces and carrying irregular ridges produced generations of daughters that were very similar to those produced by dams that laid eggs with sandy surfaces. Both groups of dams gave a significantly lower percentage of daughters laying normal eggs than did ridged-smooth mothers or normal mothers. It is probable that the granular or sandy surface is due in part to genes recessive to normal. From a physiological standpoint the production of eggs with sandy surfaces very frequently occurs in the first year of laying following a prolonged period of high production in birds that have laid normal eggs. Such a situation suggests that an exhaustion process has taken place in the shell glands. The data in this experiment were collected during February and March and do show a remarkable difference in the ability of different birds to produce normal smooth shells.

From the breeding standpoint these data indicate that breeding birds should be selected for normal shell texture in order to establish this character in the flock. The data further show that fewer daughters laying eggs with normal shell texture were produced by the small-egg line A and that the medium-egg line B gave the greatest number of daughters showing normal shell texture.

B. Character of the Ends of Eggs

For convenience in these studies the pointed end of the egg away from the air cell is designated as the "tip". The blunt end of the egg carrying the air cell is called the "butt". The eggs of all birds were examined in February or March and classified with respect to the character of the ends as rough, thin, or normal. The shells of eggs designated as rough might or might not be very porous in the end regions. Ends classed as thin were clearly very porous and carried very little mineral coating over the membranes.

In Table 7 are summarized the results in eight generations of daughters produced in the three lines from the three different classes of dams. Dams of each line were mated to full brothers on successive years to keep the male ancestry as nearly uniform as possible.

Table 7. — Character of Ends of Eggs

Dams Classified by Character of Ends of Eggs	Number of Dams	Daughters Classified by Character of Ends of Eggs							
		Character of Tips				Character of Butts			
		Rough	Thin	Normal	Percent Normal	Rough	Thin	Normal	Percent Normal
Tips rough									
Line A .	10	30	—	58	65.9				
Line B .	9	19	—	36	65.5				
Line C .	7	17	—	27	61.4				
Tips normal									
Line A .	10	4	4	80	90.9				
Line B .	17	7	—	111	94.1				
Line C .	17	20	2	123	84.8				
Butts rough									
Line A .	10					36	2	69	64.5
Line B .	6					19	—	18	48.6
Line C .	7					11	—	24	68.8
Butts normal									
Line A .	10					15	—	53	77.9
Line B .	20					13	—	123	90.4
Line C .	17					26	1	127	82.5

With respect to egg tip character there is remarkable uniformity in the three lines. The combined data show that the dams normal for shell tips produced about 40 percent more normal daughters than did the group of 26 dams which laid rough-tipped eggs.

The character of shell butts does not vary widely in the three lines. Normal dams produced about 38 percent more normal daughters than did mothers showing the rough-butt character.

These data in a general way indicate that heredity is in part responsible for abnormal egg ends. Certainly the breeder should discriminate against breeding birds whose eggs show abnormal ends. Eggs that have a rough surface at one end are most likely to show the character at the other end also.

C. Shell Porosity

Porosity has been reported to vary according to the number of shell pores and the number of pores in the external and internal shell membranes (Hays, 1927). In the present studies porosity was roughly determined by a physical examination of the general surface texture of the shell. Eggs were thus grouped as high, medium or low in porosity. The data are summarized in Table 8 for the three lines through eight generations.

TABLE 8. — EGG-SHELL POROSITY

Dams Classified by Egg-Shell Porosity	Number of Dams	Daughters Classified by Egg-Shell Porosity			
		High	Medium	Low	Percent Low
High porosity					
Line A	0				
Line B	0				
Line C	1	–	1	2	66.7
Medium porosity					
Line A	14	10	55	65	50.0
Line B	11	6	29	38	52.1
Line C	10	6	23	49	62.8
Low porosity					
Line A	6	3	10	32	71.1
Line B	15	2	12	86	86.0
Line C	13	2	24	82	75.9

Few data are available on the high-porosity group of dams. Eggs in this class are for the most part soft shelled and generally do not pass successfully through the incubation period. Even though a considerable number of birds laying these highly porous eggs were placed in the mating pens during this experiment they failed to produce a sufficient number of chicks to warrant the retention of their daughters for a year of trapnest records.

The group of dams laying eggs of medium porosity showed a rather uniform proportion of low-porosity daughters in the three lines. About half the daughters showed low porosity, the other half being classed as of medium or high porosity. The small-egg line A gave a somewhat greater proportion of high-porosity daughters than the other two lines.

The low-porosity group may be considered as normal with respect to shell porosity. A comparison of the three lines here shows that line B gave more normal daughters and that lines A and C produced about three-fourths normal to one-fourth medium or high in porosity. Genetically, high or medium porosity seems to depend on one recessive gene po. If the medium porosity dams are of the formula po po and are mated with males of the formula Po po, half the daughters will show normal porosity. Table 8 shows a close approximation to this proportion. These data are in general agreement with those of Axelsson cited by Landauer (1937).

Normal dams gave about three normal daughters to one with medium or high porosity. If these dams were of the genetic formula Po po and were mated to males of the formula Po po, three-fourths of the daughters would be normal in porosity. The proportions actually obtained were 3.7 normal to 1 medium or high in porosity. It is probable that the so-called high-porosity or thin-shelled eggs come from females pure for the factor po after the shell glands have been somewhat exhausted by continuous laying.

D. Egg Shape

A number of different indexes have been developed for egg shape to compensate for the varying diameter of the egg in relation to length. For general purposes the index proposed by Pearl and Curtis (1916) is adequate. Here the ratio of maximum diameter to maximum length is given. A normal index according to these workers is .7452. Eggs measured in the Massachusetts Station flock of Rhode Island Reds gave an index of .7338 which is in close agreement with the index of .731 reported by Axelsson (1936).

Egg shape, according to extensive studies by Asmundson (1931), is governed largely by the muscular activity of the oviduct. Since individual hens lay eggs of a characteristic shape, it is probable that the coordination of the various physiological processes varies between individuals.

In the studies to be reported on egg shape the classification was made not on the basis of measurements but purely on observation. Three general classes of eggs were described — long, round, and normal. Eggs with too great a length in proportion to diameter fell into the first class. Those eggs that were too blunt and lacked length were placed in the second class. All other eggs were considered normal in shape.

TABLE 9. — EGG SHAPE

Dams Classified by Egg Shape	Number of Dams	Daughters Classified by Egg Shape			
		Long	Round	Normal	Percent Normal
Long Eggs					
Line A	1	3	–	13	81.2
Line B	4	7	–	30	81.1
Line C	0	–	–	–	–
Round Eggs					
Line A	0	–	–	–	–
Line B	0	–	–	–	–
Line C	1	–	2	2	50.0
Normal Eggs					
Line A	19	11	2	146	91.8
Line B	22	11	5	120	88.2
Line C	23	21	5	159	85.9

Data are very limited on the use of dams for breeding that laid either long or round eggs. The limited number of long-egg dams produced a high percentage of normal daughters. The great majority of the dams used for breeding laid normal-shaped eggs. These dams averaged to produce about 90 percent of normal daughters. The large-egg line C gave a slightly greater percentage of long-egg daughters than occurred in the other two lines. The combined data in table 9 do not indicate that egg shape is governed by inherited factors.

E. Egg Shell Color

Shade of color has been studied by a number of workers already mentioned, particularly the results from crossing breeds having different egg-shell color. The studies here reported are concerned with pigment flecking on the shell and with shades of shell color in the Rhode Island Red breed. Eggs often carry brown pigment flecks that are irregularly distributed. These flecks may occur on shells of several shades of color but are more likely to occur on the darker shades.

Shell Flecking

In Table 10 are presented the experimental results in breeding from dams laying flecked eggs and dams laying uniform eggs.

TABLE 10. — EGG-SHELL FLECKING

Dams Classified by Shell Flecking	Number of Dams	Daughters Classified by Shell Flecking		
		Flecked	Uniform	Percent Uniform
Shells flecked				
Line A	2	3	17	85.0
Line B	5	7	18	72.0
Line C	3	6	20	76.9
Shells Uniform				
Line A	18	32	123	79.4
Line B	21	26	122	82.4
Line C	21	23	140	85.9

The gross data in table 10 indicate that shell flecking is not an inherited character because the group of dams laying flecked eggs and the dams laying eggs of uniform color produced the same proportions of daughters laying flecked and uniform eggs. There was furthermore no significant difference in the three lines with respect to shell flecking. Evidently the distribution of shell pigment is purely physiological and is not governed by inheritance.

Shades of Egg Shell Color

The shades of shell color in the Rhode Island Reds used in this experiment nearly approached the series given in Ridgeway's plate 29. The shades concerned ranged from white to vinaceous cinnamon. These nine shades did not correspond in color with all of the eggs but are the nearest approximation that could be selected. The following eight shades are included: white, pale pinkish buff, pale pinkish cinnamon, pale cinnamon pink, pinkish buff, light pinkish cinnamon, light vinaceous cinnamon and vinaceous cinnamon.

The egg color of the daughters produced by the different classes of dams should throw some light on the inheritance of egg color. The five dams laying white or near white eggs produced 42 daughters, one-third of which laid white eggs and two-thirds colored eggs. The majority of the daughters laying tinted eggs fell into the pale pinkish buff class, which is not far removed from white. There were, however, seven daughters in the light pinkish cinnamon group where there is considerable pigmentation.

TABLE 11. — SHADES OF EGG COLOR

Dams Classified by Shade of Egg Color	Number of Dams	Daughters Classified by Shade of Egg Color								
		White	Pale Pinkish Buff	Pale Pinkish Cinnamon	Pale Cinnamon Pink	Pinkish Buff	Light Pinkish Cinnamon	Light Vinaceous Cinnamon	Vinaceous Cinnamon	Totals
White										
Line A . .	2	9	4	–	1	–	5	–	–	
Line B . .	1	2	4	–	–	–	1	–	–	
Line C . .	2	3	9	1	1	1	1	–	–	
Totals .		14	17	1	2	1	7	–	–	42
Pale Pinkish buff										
Line A . .	10	18	21	8	5	1	6	3	–	
Line B . .	10	8	35	4	1	–	7	3	–	
Line C . .	9	2	21	2	3	–	9	3	–	
Totals .		28	77	14	9	1	22	9	–	160
Pale pinkish cinnamon										
Line A . .	3	6	14	5	1	–	5	–	–	
Line B . .	4	1	6	1	3	1	9	8	–	
Line C . .	0	–	–	–	–	–	–	–	–	
Totals .		7	20	6	4	1	14	8	–	60
Pale cinnamon pink										
Line A . .	2	1	12	–	4	3	6	3	–	
Line B . .	1	–	1	–	–	–	3	1	–	
Line C . .	3	–	8	1	5	–	12	9	–	
Totals .		1	21	1	9	3	21	13	–	69
Pinkish buff										
Line A . .	0	–	–	–	–	–	–	–	–	
Line B . .	0	–	–	–	–	–	–	–	–	
Line C . .	1	–	5	–	–	1	–	–	–	
Totals .		–	5	–	–	1	–	–	–	6
Light pinkish cinnamon										
Line A . .	2	–	3	1	2	1	13	7	–	
Line B . .	7	–	6	1	–	5	22	18	4	
Line C . .	5	4	19	4	4	3	21	5	–	
Totals .		4	28	6	6	9	56	30	4	143
Light vinaceous cinnamon										
Line A . .	1	2	4	1	–	–	–	–	–	
Line B . .	3	1	3	–	1	1	3	6	3	
Line C . .	4	1	6	2	2	3	8	8	–	
Totals .		4	13	3	3	4	11	14	3	55
Grand Total		58	181	31	33	20	131	74	7	535

Twenty-nine dams in the lowest pigmented class, pale pinkish buff, had 160 daughters. About one daughter laid white eggs to five laying tinted eggs. Among those laying tinted eggs, the prevailing shade was pale pinkish buff, but a greater proportion showed intermediate shades than in the preceding group.

The next deeper pigmented class of dams was the pale pinkish cinnamon group. This class of dams gave white to pigmented daughters in the proportion of one white to 8 pigmented. No dams of this class belonged to line C, but lines A and B behaved in the same general way. A significantly greater proportion of daughters of this group fell into the deeper pigmented classes.

The pale cinnamon pink class is next in amount of pigmentation. Six dams produced 69 daughters. Only one of this number laid white-shelled eggs, about one-third laid lightly pigmented eggs, and fully one-half laid deeply pigmented eggs.

The moderately deep pigmented class, light pinkish cinnamon, was represented by 14 dams and 143 daughters. Only four daughters produced white eggs, and 34 of the daughters showed deeper shell pigmentation than their dams. This fact affords good evidence that shell pigmentation depends on multiple factors and that several factors accumulate to produce deeper shell pigments.

Light vinaceous cinnamon represents the most deeply pigmented class of dams. Eight dams produced 55 daughters. There was still a small number of white shell daughters, but about half the daughters belonged to the deeply pigmented classes.

The question arises at this point as to what is the typical shade of shell color in the Rhode Island Reds used in this experiment. It is further important to know whether the typical color is the most desirable color and to secure as much information as possible on how to produce a population uniform for the shade desired.

The totals at the bottom of table 11 are of interest in this connection. The most common single color is pale pinkish buff which represents a low degree of pigmentation and is too light in shade to be desirable. The light pink cinnamon shade prevails in the daughters that laid eggs with more deeply pigmented shells, and the light vinaceous cinnamon shade appeared in large numbers. It is probably justifiable to assume that a shell color approaching light pinkish cinnamon or light vinaceous cinnamon is most desirable in Rhode Island Reds. As already pointed out, dams belonging to either of these two classes gave very few daughters which laid eggs of the lighter shades. These facts indicate that two or more cumulative genes are necessary to produce the deeper pigmented shades. Crosses between light and dark shell types might be expected to give blending, and dark shell birds would give a range in color shades of daughters unless the dams and sires were homozygous for the pigment genes concerned. Egg shell color can be intensified by selection for breeding females laying deeply pigmented eggs and males that carry a similar inheritance. In this way, after a few generations the flock should show uniformity in egg color of the desired shade and freedom from white or lightly pigmented eggs.

SUMMARY

Three lines of Rhode Island Reds with respect to egg size were carried through nine generations to study the genetic behavior of egg weight, egg shape, shell texture, shell porosity, and shell pigmentation. Some of the more important deductions made were as follows:

Part I. Egg Weight

1. Egg weight to January first was a very good criterion of prospective egg weight in February or March. The mean egg weight to January first should not fall below 53 grams (22.5 ounces to the dozen) if 56.7-gram eggs (24 ounces to the dozen) are expected in February or March.

2. Winter egg weight showed an intimate correlation with both hatching-season egg weight and annual egg weight, with strictly linear regression.

3. Hatching-season (February and March) egg weight was intimately correlated with annual egg weight. The data showed that birds averaging 56.7-gram eggs (24 ounces to the dozen) for the full year should lay eggs weighing about 58.2 grams (24.7 ounces to the dozen) in the hatching season.

4. The basis for selecting breeders did produce a significant difference in hatching-season and annual egg weight between line A and lines B and C, but not between line B and line C.

5. In all three lines, maximum egg weight occurred in March, or at a mean age of about eleven months.

6. The mean annual egg weight was significantly greater in line B than in lines A or C and slightly greater in line C than in line A.

7. The data in general indicated that there is no advantage in selecting for hatching purposes, pullet eggs that weight more than 26 ounces to the dozen.

8. Most satisfactory breeding females for large eggs were those attaining standard egg weight within sixty days.

9. Egg size depends in inheritance upon three dominant genes A, B, and C. Gene A is epistatic to both B and C and produces small eggs. Either gene B or gene C gives an egg weight above 24 ounces to the dozen in the normal hatching season. Genes B and C acting together give very large egg size.

Part II. External Egg Characters

1. Ridged shell condition is not inherited, but the sandy shell character does depend on recessive genes.

2. High shell porosity depends largely on one recessive gene (po).

3. Available data do not indicate that egg shape is governed by inheritance.

4. Shell flecking is probably independent of inheritance.

5. Multiple factors are concerned in shell pigmentation. Eight shades of color were observed ranging from white to vinaceous cinnamon. From the white or near white there was a gradation to pinkish tints and from pinkish tints to brown tints.

6. A shade of color near light pinkish cinnamon or light vinaceous cinnamon is probably most desirable, and females laying such eggs gave very few daughters laying light colored eggs.

REFERENCES

Asmundson, V. A. 1931. The formation of the hen's egg. Sci. Agr. 11: 1-50.

Atwood, Horace. 1923. Certain correlations in the weight and number of eggs and the weight of fowls. W. Va. Agr. Exp. Sta. Bul. 182.

Atwood, Horace. 1926. Some factors affecting the weight of eggs. W. Va. Agr. Exp. Sta. Bul. 201.

Axelsson, Joel. 1936. Untersuchungen über die Form der Hühnereier. Proc. Sixth World's Poultry Congress.

Benjamin, E. W. 1920. A study of selections for the size, shape, and color of hens' eggs. N. Y. (Cornell) Agr. Exp. Sta. Mem. 31.

Bennion, N. L., and D. C. Warren. 1933. Temperature and its effect on egg size in the domestic fowl. Poultry Sci. 12 (2): 69–82.

Curtis, Maynie R. 1914. Factors influencing the size, shape and physical constitution of the egg of the domestic fowl. Maine Agr. Exp. Sta. Bul. 228.

Hadley, Philip, and Dorothy W. Caldwell. 1920. Studies on the inheritance of egg weight. R. I. Agr. Exp. Sta. Bul. 181.

Hays, F. A. 1927. Physical character of eggs in relation to hatchability. Poultry Sci. 6: 196–200.

Hays, F. A. 1929. The inheritance of egg weight in the domestic fowl. Jour. Agr. Res. 38 (9): 511–519.

Hays, F. A. 1930. Increase in egg weight during the pullet laying year. Proc. Twenty-Second Ann. Meeting of Poultry Sci. Ass. pp. 16–19.

Hays, F. A. 1934. Time interval from first egg to standard egg weight in Rhode Island Red pullets. Mass. Agr. Exp. Sta. Bul. 313.

Hurst, C. C. 1905. Experiments with poultry. Report to the Evolution Committee of the Roy. Soc. 11: 131.

Hurst, C. C. 1921. The genetics of egg production in White Leghorns and White Wyandottes and its application to poultry breeding. Trans. First World's Poultry Congress, p. 3.

Jull, M. A. 1924a. Egg weight in relation to production. Poultry Sci. 3 (3): 77–88.

Jull, M. A. 1924b. Egg weight in relation to production. Poultry Sci. 3: 521.

Jull, M. A., and A. B. Godfrey, 1933. Mean annual egg weight in relation to mean weight of first ten eggs laid. Poultry Sci. 12 (5): 310–312.

Kopec, Stephen. 1924. Beobachtungen über die Variabilität der Dimensionen, der Form und des Gewichtes der Hühnereier. Mem. Inst. Natl. Polon. Econ. Rurale Pulawy 5: 294.

Kopec, Stephen. 1927. Beiträge zur Kenntnis des Mechanismus der physiologischen Shalenfarbenvariabilität der Hühnereier. Sond. Arch. f. Geflüg. Jahr. 1, Heft. 9.

Landauer, W. 1937. The hatchability of chicken eggs as influenced by environment and heredity. Conn. Agr. Exp. Sta. Bul. 216.

Maw, A. J. G., and W. A. Maw. 1932. A method of estimating the mean annual egg weight. Sci. Agr. 12 (5): 281–286.

Parkhurst, R. T. 1933. Some factors affecting egg weight in the domestic fowl. Poultry Sci. 12 (2): 97–111.

Pearl, Raymond, and Maynie R. Curtis. 1916. Dwarf eggs of the domestic fowl. Maine Agr. Exp. Sta. Bul. 255.

Punnett, R. C., and P. G. Bailey. 1920. Inheritance of egg color and broodiness. Jour. Genetics 10: 277.

Waters, N. F., and J. C. Weldin. 1929. Studies on the inheritance of egg weight. R. I. Agr. Exp. Sta. Bul. 218.

Wilson, Wilbur, and D. C. Warren. 1934. Initial egg weight as a basis of prediction of maximum egg size. Poultry Sci. 13 (1): 52–55.

Publication of this Document Approved by Commission on Administration and Finance
3,500—9-'37. No. 1727.

414b
.3
.345

INIA POLYTECHNIC INSTITUTE
[illegible]

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 345 August 1937

Agri. Library
File No. 3

Woody Plants for New England Gardens, Parks and Roadsides

By George Graves

This is an attempt to evaluate hardy woody plant materials and to summarize expert opinions regarding their adaptability for landscape planting in New England.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

WOODY PLANTS FOR NEW ENGLAND GARDENS, PARKS AND ROADSIDES

By George Graves, Assistant Research Professor of Nurseryculture

This is the report of an investigation which set out to determine by selective sampling of current thought just which few of the thousands of available woody plants are now deemed most worthy, or necessary, for the ample development of the several phases of gardens, parks and roadsides in New England. By New England is here meant the territory taken in by the arc of a circle of one hundred and fifty miles radius, centering in downtown Boston; or for areas of like cultural conditions elsewhere.

The differing areas under consideration, the diversified types of planting in progress, and the varied attitudes and preferences of horticulturists, have all influenced the finished report. Many fine plants have been eliminated because of redundancy. Some material of little general usefulness has been included to provide for specific planting conditions. In some cases, where large groups of forms of equal value present no readily apparent first choice, mere representative suggestions have been made. In all except the rock garden suggestions, numerous rare and interesting species have been left out because of lack of common availability. The rigorous climate of New England, too, has had its curtailing influence.

Thus, so far as possible, the general idea of evaluation without attempt at dogmatic standardization has been followed through. The plants have been considered for their habit, garden aspect, and cultural behavior, and the resulting data brought into a single treatment. It remains for the individual reader to consider his problem, and use that portion of this study which is applicable to it.

The first of the three main purposes actuating this study was the evaluation of those species and garden varieties which have been finding their way into the development of home grounds and other similar more intimate areas — plants which, when so used, are considered not for themselves alone but as building units to be assembled into the fabrics of completed pictures. Obviously, the selection of garden plants on any such basis is not be to approached from the point of view of the collector interested in minute variations; rather it becomes necessary to settle upon worth-while forms which best express particular, desirable lines of variation. Hence, the opinions given below as regards this particular sort of plant material represent a limiting process.

The second objective has been to consider woody plant materials suitable for the development of broader, wilder roadside areas in keeping with the physiognomy of the native landscape. With the recent increased interest in this sort of planting, it has become, by example, painfully apparent that there is much need for a deeper appreciation of the way in which plants live together in undisturbed natural areas, and why they do or do not adapt themselves to particular conditions. A better realization of some of these basic principles of the economy of the untouched natural landscape will reveal possibilities for happier treatment — with both native and suitable foreign materials — of traffic lanes leading through seemingly ungardened countrysides. The suggestions which follow are made with the appreciation that roadside development may be looked upon most definitely as being a job of conservation of either natural planting or nature's way of planting. Thus, the designer of more gardened areas will find suggested here materials which can be of little benefit in more restrained plantings.

The third motive which has influenced this report has been the selection of woody plants of small stature adaptable for use in rock gardens and similar limited areas. This portion of the study moves in the direction taken by the plant hobbyist, the man who grows plants for their interest as plants and cares not whether they have anything to contribute to a general landscape picture. Though many of the plants listed here are of this sort, many more of these dwarf, slow-growing, or procumbent materials do have possibilities for wider use. Then, too, a glance at almost any portion of suburban America will reveal the need for more careful location of plants on the basis of their potential ultimate size. Even so, it should be understood that many of the rock-garden shrubs suggested here are rare in cultivation, difficult to obtain, and will probably never be taken up by the trade in general. Such suggestions are made for the benefit of that increasing group of specialists who spend their time at this sort of thing.

Method of Presentation of Subject Matter

The main body of the text of this bulletin consists of an alphabetical arrangement of the several genera treated. Under each genus are considered the one or more species or garden forms which seem best to express any particular lines of desirable variation. Attached to each listing is to be found a short description of that item. These descriptions are not be to looked upon as technical accounts but rather as hints to garden value or other cultural particulars. As a still further aid to evaluation on the basis of garden usefulness, three different intensities of boldness of type face are employed to express a somewhat arbitrary scoring of the several plants: boldface capitals are used for the most desirable; boldface small capitals for those varieties which are somewhat less valuable; and small boldface type for the least desirable of the species listed. This scoring is intended to indicate preference both within each genus and within larger groups of plants of similar habit or garden value.

Appended also are a few very general lists which analyze the plants on the basis of habit or, in certain cases, of outstanding adaptability for specific uses. It must be recognized that plants, being living things, do not lend themselves readily to fixed groupings, and that such an analysis must be considered only suggestive. Particularly necessary is it to so qualify the artificial assemblage which includes those plants loosely classed as ground-cover materials or undershrubs. Though this lumping together of plants of diverse aspect and habit — each with some individual property to make it useful in the solution of some one of the numerous planting problems — may serve as a guide, information so tabulated must be looked upon as but an index of possibilities. For definite planning, reference should be made to the foregoing text, or to the fundamental publications.

Nomenclature

The names of plants as here given — as concerns determination, spelling, and usage — are based on Rehder's "Manual of Cultivated Trees and Shrubs." Thus, with the single lapse into the horticultural practice of characterizing all forms, phases, and natural varieties as *varieties*, these listings conform to the rules in use internationally by plant taxonomists. The common names given are, for the most part, those recommended by "Standardized Plant Names."

For plants having no such colloquial appellations extant, no attempt has been made to coin everyday terms to represent them in English.

In an effort to preserve the alphabetical order, named garden hybrids are either inserted in the list under one of their parent species, or listed in separate groups under a common horticultural designation. The names of hybrid plants which have recognized binomials are preceded by the symbol "X".

Sources of Information and Opinion

Acknowledgment is due a number of general practitioners and specialists in horticulture whose current opinions were sampled during the preparation of this paper. Information of a general nature as to the list in its entirety was supplied by Mr. Russell N. Barnes of the Connecticut State Highway Department; Prof. Lyle L. Blundell of the Massachusetts State College; Mr. Henry E. Downer of Vassar College; Prof. Stephen F. Hamblin of the School of Landscape Architecture, Harvard University; Mr. William H. Judd of the Arnold Arboretum; Mr. Harlan P. Kelsey, Nurseryman, of East Boxford, Massachusetts; Mr. L. F. Kinney, Horticulturist, of Kingston, Rhode Island; Mr. Hans J. Koehler of Olmsted Brothers, Landscape Architects, Brookline, Massachusetts; Mr. James E. Mitchell, Nurseryman, of Barre, Vermont; Mr. Lester W. Needham, Nurseryman, of Westfield, Massachusetts; Mr. Jacob Van Heiningen, Nurseryman, of South Wilton, Connecticut; Mr. Willard Van Heiningen, Nurseryman, of South Wilton, Connecticut; Mr. Wilfred Wheeler of Hatchville, Massachusetts; Dr. Donald Wyman of the Arnold Arboretum; and Mr. Richard M. Wyman, Nurseryman, of Framingham, Massachusetts.

Acknowledgment is also given to Mr. L. C. Bobbink, Nurseryman, of Rutherford, New Jersey, for his suggestions for the Rose list. Dr. Clement G. Bowers has kindly given advice on the treatment of Rhododendron. Mr. Charles Francis Jenkins has commented on the varieties of Tsuga included here. Dr. Alfred Rehder has, in addition to furnishing a guide to proper nomenclature, joined in the assembling of the list of rock-garden shrubs. The partial list of garden Clematis as given here has been made up with the aid of Col. J. E. Spingarn of Amenia, New York.

All photographs reproduced here are from the collection of the Arnold Arboretum, with the following exceptions. The illustrations of fruits of *Callicarpa japonica*, *Malus Sargenti*, and *Viburnum Wrightii* are from photographs made by Mr. Herbert W. Gleason. From the files of the Massachusetts Horticultural Society have come the pictures of *Pinus Strobus*, *Taxus cuspidata* var. *Thayerae* and *Wisteria floribunda*.

Notes on Species and Varieties

X Abelia grandiflora GLOSSY ABELIA

A top-tender, half-evergreen, shiny-leaved shrub which has not proved satisfactory in New England except in the most sheltered spots, or in warmer areas such as parts of Cape Cod. Its freely borne white, flushed-pink flowers appear from June to November, followed by a display of persistent purplish sepals. Medium in texture and size.

ABIES THE FIR

Because of their love for cool, clean, humid air, the Firs may be looked upon as plants for foggy mountainous sections or, sometimes, for humid regions near the sea. In general, they abhor dry inland situations or the smoky air of densely populated areas. Another hindrance to their widespread successful cultivation is a taproot which may at times make their transplanting difficult. The species listed are those which seem to be most amenable to general garden conditions. Any of them should be used only if a tall, stately conifer with well-separated whorls of branches is needed.

Abies cilicica CILICIAN FIR

At maturity this species becomes a hundred-foot, gray-barked, pyramidal, evergreen tree with a lower-branch spread of twenty or more feet. Its leaves, green above and streaked white below, are so arranged that a noticeable V-shaped depression appears on the upper surfaces of the branches. A pleasing, large tree which has proved successful in parts of New England as a substitute for the less satisfactory *A. Nordmanniana.*

ABIES CONCOLOR WHITE FIR

This is probably the best known and most adaptable of the Firs. Although, in its native Colorado, it may become a bluish green leaved evergreen tree growing to a height of two hundred feet or more, few such specimens are in cultivation. There are garden varieties based on the differing color (dull green to silvery-white) of the upward-curved, two- to three-inch leaves. Other varieties are determined by habit (globose, dwarf, pyramidal, etc.) or leaf size. However, this species is seldom propagated vegetatively, and most cultivated plants are but selected seedlings which have been picked for their individual appearance. The common practice of shearing small nursery plants into compactness may permanently cripple the lowest branches of resulting large specimen trees.

Abies Fraseri FRASER FIR

Being of about the same size and aspect, this Alleghenian expression of *A. balsamea* has little other garden value than to replace the Balsam Fir in southern New England gardens. It will, in cultivation, hold its lower branches better than the northern form.

ABIES HOMOLEPIS (*A. brachyphylla*) NIKKO FIR

A hardy, dark-foliaged, hundred-foot, evergreen tree which has proved satisfactory for cultivation in eastern gardens. Its upturned branches reach out to form a broadly pyramidal, purple-coned tree which is handsome while still very young. Rated as one of the best.

ABIES VEITCHII VEITCH FIR

A species which also develops the pyramidal habit in quite young plants. The crowded, blunt-tipped leaves, dark green above and with prominent white bands beneath, are all turned toward the ends of the branches. A hardy species of high rating for New England use.

ACANTHOPANAX SIEBOLDIANUS (*A. pentaphyllus*) FIVE-LEAVED ARALIA

A prickly, arching, deciduous shrub which, when grown naturally, becomes five to ten feet high. Since only the male plant is reported to be in cultivation, the fruits are not seen in gardens. Here is a plant which will withstand considerable shade and drought, can be pruned into a satisfactory hedge, and transplants readily. It is sometimes attacked by aphids.

Acer carpinifolium HORNBEAM MAPLE

A round-headed, small, deciduous tree of not over thirty feet, which has dense branching and foliage, resembling that of the Hornbeam, which in autumn turns yellow.

Acer japonicum var. **aconitifolium** (var. *Parsonsii*) FERNLEAF MAPLE

This species is usually seen in cultivation as a large, bare-based shrub with grayish wood and deeply divided, light-green leaves, which may be looked upon as a somewhat over-sized but not bright-colored "Japanese" Maple. Not a plant for cold inland locations.

Acer Negundo BOX ELDER

A hardy, quick-growing, variable, native Maple which is now considered to be of little ornamental value. Its ability to withstand trying atmospheric and soil conditions makes it useful at times for screen planting.

Acer palmatum JAPANESE MAPLE

A large shrub or a small tree with a broad, low head of not more than about fifteen feet in diameter. This is the pleasant, green-leaved form of a variable species having numerous garden varieties which are based on color or shape of the leaves. While these varieties, particularly those which differ only in intensity of red leaf coloration, are separated in botanical collections, they are now much confused in commerce. Much of the nursery material consists of a mixed lot of selected seedlings on which the leaves are red in the spring but become green as the season advances. The cut-leaf forms are propagated vegetatively and, while not varying in appearance, have their names confused. Such material should be bought only on inspection and, because of possible garden redundancy, planted thoughtfully.

Acer pennsylvanicum STRIPED MAPLE

A native tree growing to some forty feet, which owes its possible value for use in wild woodland development to the winter effect of its white-striped greenish stems.

ACER PLATANOIDES NORWAY MAPLE

This commonly planted Maple, with its spring show of yellowish flowers, later canopy of dark-green, lustrous leaves, and stocky symmetrical crown, has been much planted as a street tree. If given ample root run in loose, moist soil, it will develop into a fine older plant. Not so, however, will be its behavior if crowded into a narrow space in sterile soil. Like the Sugar Maple, its roots and shade will interfere with grass or smaller plants placed beneath it. Var. **COLUMNARE** is one of the several fastigiate plants deserving of greater use for tall, narrow screens in place of the Lombardy Poplar.

ACER RUBRUM RED MAPLE

This is the fast-growing inhabitant of moist soils which, with its red flowers of early spring and red or yellow autumn foliage, is such a real part of the native landscape. In cultivation it can be used on fertile, higher soils. It is not so intolerant of undergrowth as are some of the other large Maples. Var. **COLUMNARE** develops into a broad column. Var. **SCHLESINGERI** represents a clon, the leaves of which invariably turn a brilliant scarlet in autumn.

ACER SACCHARUM SUGAR MAPLE

The well-known hard Maple with a many-branched, broad, symmetrical head, rough bark, and dense, light-green foliage which turns yellow or sometimes red in autumn. Not a tree for limited areas on poor soil where its voracious roots and deep shade will discourage underplanting. Some species of the genus Sedum are often used beneath it in place of grass. Var. **MONUMENTALE**, with ascending branches, forms a very slender column of far more permanence than the pest-ridden Lombardy Poplar.

Acer spicatum MOUNTAIN MAPLE

A very large, deciduous shrub of value in wild planting because of its orange and scarlet autumn coloration, its grayish leaves, and its late-summer show of red fruits.

Acer tataricum TATARIAN MAPLE

A somewhat larger shrub than the Mountain Maple, with lustrous, dark-green foliage turning yellow in autumn, and a show of red fruits in late summer.

ACTINIDIA ARGUTA BOWER ACTINIDIA

A hardy, rugged, twining, shrubby, deciduous plant which will be a climber if given high support to ascend. Without such support it will elongate less vigorously to cover boulders and rocky areas. The leaves are large and shiny with reddish petioles. Its somewhat insignificant white flowers of summer are followed by greenish-yellow edible fruit.

X AESCULUS CARNEA RED HORSECHESTNUT

A hybrid having slightly smaller stature than *A. Hippocastanum*, but with darker green and crisper foliage. It is also reported to be more drought-resistant than the common Horsechestnut. Extremes of the color range of the late May or early June flowers may be had in var. **plantierensis**, pinkish-white; and var. **Briotii**, bright scarlet.

Aesculus Hippocastanum HORSECHESTNUT

With its large, divided leaves and white flower spikes of late May, this well-known plant is properly rated as one of the showiest of flowering trees. Against this may be charged its inability to carry on in cramped or dry situations; the susceptibility of its foliage to the destructive but easily controlled leaf-blotch disease, and its all-season bad habit of casting off unwanted vegetative parts and fruits. Var. **Baumannii** is now finding some favor in that its double flowers tend to make it a less "dirty" tree.

Aesculus parviflora BOTTLEBRUSH BUCKEYE

A broad-spreading, deciduous shrub with erect stems three to ten feet in height, which grows best in rich, moist, loamy soil. It has slender panicles of white flowers in late July and early August. Formerly much used as a specimen plant. Ability to withstand some shade accounts for its modern use as ground cover in thin woods.

AETHIONEMA GRANDIFLORUM STONE-CRESS

This and several other species are "die-back" shrubs which are quite adaptable for well-drained, sunny locations in the rock garden. Its simple branches, reaching out and then up to some eighteen inches, bear bluish leaves and pink flowers in June. The genus has many herbaceous species.

Ailanthus altissima (*A. glandulosa*) TREE OF HEAVEN

Although at home in backyards of almost all crowded eastern cities, this tree with its interesting compound foliage and showy flower parts usually resists attempts to make use of it in any conventional manner on good soil. When both sexes are present, it will readily take to the wild in dry, open woods. It is usually represented in controlled planting by the female plant, the flowers of which do not give off the objectionable odor so characteristic of those of the male. Purple-fruited forms are considered to be more ornamental.

AKEBIA QUINATA FIVE-LEAF AKEBIA

A hardy, high-climbing, thin, sinuous, deciduous vine with greenish stems which form a loose, open covering for pillars or screens. The shining, long-persistent, half-evergreen leaves permit its possible use as a ground cover for open, sunny, well-drained spots. In New England its fragrant, dark-colored, inconspicuous, spring-borne flowers rarely produce in autumn the large, sickishly sweet-fleshed, edible, blue fruits. When completely naturalized, it may become quite rampant.

Althaea — See Hibiscus

Alyssum argenteum SILVER ALYSSUM

A hardy subshrub with silver-gray foliage and clusters of yellow flowers which appear later than those of *A. saxatile* and continue throughout the summer. Reaching a height of some eighteen inches, this plant is suitable for banks, retaining walls, or the top of the large rockery.

ALYSSUM SAXATILE var. COMPACTUM DWARF GOLDEN-TUFT

This is the familiar, May-flowering, yellow subshrub so frequently used on banks and walls throughout the East. Many of the plants so labeled are really seedlings of type material. Such misnamed specimens have rapid lateral spread and soon become too rampant for the small rockery.

AMELANCHIER CANADENSIS DOWNY SHADBLOW

Compared with *A. laevis*, the more common Shadblow, this species is of slightly lesser stature, more bushy in habit, and less showy in flower. A plant for wide borders or woodland planting.

AMELANCHIER LAEVIS ALLEGHENY SHADBLOW

A deciduous native shrub or multiple-stemmed tree growing to a height of some forty feet. The smooth, rounded leaves, purple upon first expanding, the numerous hanging clusters of small, open, white, May-borne flowers, and a graceful habit, all go to make this one of the best of the several eastern Shadblows, all of which have ornamental value. The purple fruit is edible and sweet in taste. Something for the edges of woodlands or roadsides.

AMELANCHIER STOLONIFERA RUNNING SHADBLOW

Limited to a height of some four or five feet and able to spread out from a common center by free-growing suckers, this deciduous plant has possibilities as a ground cover for large areas along roadsides. Its leaves and flower stems are usually of a woolly whiteness. Its white flowers are borne in upright clusters and appear somewhat later than those of *A. laevis*, to be followed in midsummer by edible fruits.

Ampelopsis — See also Parthenocissus

AMPELOPSIS ACONITIFOLIA MONKSHOOD VINE

A slender, tendril-climbing, deciduous vine which in habit and aspect of foliage resembles a cut-leaf grape. The inconspicuous green flowers are followed by berries which in process of maturing change in color from blue to orange throughout the summer and autumn. It does not make a dense screen. Cultural requirements are about the same as for wild grape.

AMPELOPSIS BREVIPEDUNCULATA (*A. heterophylla*) PORCELAIN AMPELOPSIS

A strong-growing, deciduous, tendril climber having grape-like foliage. Valuable because of autumn show of berries in their several ripening color stages — lilac, green, turquoise, or whitish — which appear simultaneously. A plant which can form a dense screen on trellises or a fine cover for dry walls, rocky ledges, or barren places. It likes full sun but will withstand partial shade. Var. **elegans** has silver variegated leaves.

Andromeda glaucophylla Downy Bog-Rosemary

A twelve-inch native shrub having undersurfaces of its narrow evergreen leaves white, and bearing pinkish flowers in early summer. Suitable for use in rock or wild gardens in situations which will support the Cranberry.

Andromeda — See also Pieris

Arborvitae — See Thuja

ARCTOSTAPHYLOS UVA-URSI Bearberry

A desirable, prostrate or trailing shrub which has small, evergreen leaves and bright red fruits. Native to open, sandy wastes near the coast or on higher ledges inland, this plant can be made happy as a ground cover on well-drained, slightly acid garden locations. Best planted as small plants out of pots.

Aristolochia durior (*A. macrophylla*) (*A. Sipho*) Dutchman's Pipe

An old-time favorite which is aptly named because of its odd-shaped, inconspicuous flowers of May and June. It is a slow-growing, deciduous vine which sends its greenish stems twining and clambering up to smother any convenient near-by object. The overlapping of its large, dull-green leaves forms an eye-proof screen. In the past it was usually grafted on the roots of other species, but true seedling plants are now becoming available.

ARONIA ARBUTIFOLIA Red Chokeberry

Erect, loose, deciduous shrub growing six to ten feet in height, with glossy, green foliage, and whitish flowers appearing in May or June, followed by bright to dull red, quite showy, long-persistent, autumn berries which are attractive to birds. A somewhat straggling growth habit indicates its use only in large mass or natural planting along roadsides, in which situations its fruiting effect is pronounced.

Aronia melanocarpa Black Chokeberry

This differs from the red-fruited species in having shining black fruit and in being less than a yard in height. It can be used for bank or roadside planting and may be had in taller-growing varieties, the best of which is var. ELATA. The fruits of this species do not persist as do those of the red-fruited chokeberry.

Arrow-wood — See *Viburnum dentatum*

Ascyrum hypericoides St. Andrew's Cross

A small, much-branched, yellow-flowered native shrub which is sometimes brought in from sandy, open woodlands to rock gardens.

Ash — See Fraxinus

Azalea — See Loiseleuria and Rhododendron

Baccharis halimifolia Groundsel-Bush

A rapid-growing, shining-leaved, much-branched shrub of eastern seabeaches and salt marshes, which will grow with its roots in salt water or do well on neutral soil inland. It bears inconspicuous white flowers in September, followed on the female plants by seeds to which are attached showy clusters of fluffy white down. It is more top-hardy than many Weigelas or Deutzias and has possibilities, particularly near the seashore, both as an ornamental plant and as a material with which to fight erosion.

Bamboo — See Sasa

Barberry — See Berberis

Bayberry — See Myrica

Beautyberry — See Callicarpa

Beautybush — See Kolkwitzia

Bearberry — See Arctostaphylos

Beech — See Fagus

Benzoin — See Lindera

BERBERIS BARBERRY

A large group of deciduous and evergreen shrubs which, where all species are hardy, presents a great many fine garden forms differing widely in habit, texture, and general aspect. Harsh local climate, however, seriously restricts their general use in most of New England. Here are listed some of the forms which have been found to be more satisfactory in the northeastern part of the country.

BERBERIS AMURENSIS var. JAPONICA HAKODATE BARBERRY

A ten-foot deciduous shrub which may be used as a substitute for the Common Barberry. Unlike *B. vulgaris* this Asiatic variety has straight, upright branches from which in late autumn the large, attractive fruit clusters hang in much the same manner as do the flowers of *Enkianthus campanulatus*. Its leaves, too, are of a lighter shade of green. Like the Common Barberry, this plant naturalizes readily in open woods.

BERBERIS BUXIFOLIA var. PYGMAEA DWARF MAGELLAN BARBERRY

A dwarf, compact, thornless form of one of the hardiest species of evergreen Barberries. Something for the rock-garden collection.

Berberis candidula

A dwarf Barberry for the rock garden. The shining leaves with few spines and white undersurfaces are borne on smooth branchlets. Related to *B. verruculosa.*

Berberis dictyophylla CHALKLEAF BARBERRY

A deciduous species with little garden value beyond the possible winter effect in wild plantings of its white young wood. So used, it would compete with some of the bloomy-stemmed Raspberries.

Berberis Julianae WINTERGREEN BARBERRY

A top-tender, upright, evergreen shrub, the branches of which will seldom survive enough inland New England winters to attain their potential height of some six feet. Its narrow, spiny, persistent foliage and blue-black fruits make it worth planting in warmer areas of the North.

BERBERIS KOREANA KOREAN BARBERRY

Now that it has been determined definitely as not being a host to the wheat rust, this thick-branched, upright, six-foot, deciduous shrub will probably be more used. Because of its bright-green, rounded leaves turning to red in autumn, and its long-persistent red fruits which follow the yellow flowers of May, it should become a shrub for more general planting.

X BERBERIS MENTORENSIS

A garden hybrid of recent introduction which, because of its somewhat upright branching and large, long-persistent leaves, is being advocated for hedge making.

BERBERIS THUNBERGII JAPANESE BARBERRY

This is the multiple-branched, prickly-stemmed, heavy-fruited plant which typifies Barberry in the public mind. A fine, hardy, deciduous shrub for use in groups or informal unpruned hedges. The too common practice of clipping it into formal hedges is destructive of its true beauty and garden usefulness. Fruits attractive to birds. Var. **atropurpurea** is a purple-leaved shrub for thoughtful use in open, sunny spots. Var. **MINOR** is a slow-growing, miniature form quite suitable for low, compact hedges. Var. **ERECTA**, TRUEHEDGE COLUMBERRY, is a recent introduction which promises to be truly adapted to use in formal clipped hedges. With every shoot of upright habit, this hybrid lends itself to forming thick, easily managed hedges with a minimum of shearing.

Berberis triacanthophora THREESPINE BARBERRY

Another top-tender, evergreen species with slightly smaller leaves, thinner branches, more spreading habit, and less ultimate height than *B. Julianae.* Fruits less black because of bloomy covering.

BERBERIS VERNAE VERNA BARBERRY

The narrow leaves and numerous thin, spreading stems make this a fine-textured, deciduous shrub of medium height. The dense clusters of small yellow flowers of spring give way to an autumn show of red berries. One of the better Barberries for use in shrub groups.

Berberis verruculosa WARTY BARBERRY

Also top-tender, this evergreen species has rounder, less spiny, glossier leaves, a more compact habit, and less ultimate height than either *B. Julianae* or *B. triacanthophora.* Its yellow, late-spring flowers, borne in prominent clusters, are followed by violet-black fruits.

BERBERIS VULGARIS EUROPEAN BARBERRY

A very hardy, often naturalized, spreading-branched, informal, deciduous shrub with numerous garden varieties. Dull in foliage, its greatest landscape value comes from its habit of growth and the late autumn show of large red fruits borne in hanging clusters. Fruits much enjoyed by birds. This species is a host to the wheat rust, and hence is to be shunned in grain-growing sections.

BETULA LENTA SWEET BIRCH (CHERRY BIRCH)

A seventy-five foot, reddish-barked, native deciduous tree which has a pleasing pyramidal habit while young. Catkins showy in the spring. A tree with a real place in park or roadside development.

Betula nana DWARF ARCTIC BIRCH

A slow-growing, round-leaved, alpine Birch which can be used as a specimen in the large rockery. It develops a much-branched, spreading top which is seldom more than two feet in height.

Betula nigra RIVER BIRCH

Another tall, native, deciduous tree which, because of its pleasing habit and the ragged brown bark of its larger stems, deserves to be preserved on moist, sandy situations in semi-wild areas.

BETULA PAPYRIFERA CANOE BIRCH

The taller-growing White Birch of northern New England. Both the plant and its possibilities are well known to everyone.

BETULA PENDULA var. DALECARLICA Cutleaf Weeping Birch

With white bark, branchlets of weeping habit, and fine-cut leaves, this variety has been a garden stand-by for many years. It, too, must now be planted with its ultimate destruction by wood-boring insects in mind.

BETULA PENDULA var. FASTIGIATA Pyramidal White Birch

Combining white bark with a pleasing columnar form caused by the vertical habit of its slightly sinuous stems, this deciduous tree of medium height should be rated as one of the finest of upright woody plants. Unfortunately, its trunk is a host to a boring insect which is killing off most of the larger European Birches in New England.

Betula populifolia Gray Birch

This is the short-lived Birch which inhabits dry or sometimes very wet waste land throughout southern New England. It is usually seen as a clump or a multiple-stemmed tree which well deserves consideration as a real part of the native landscape picture. Its leaves, like those of other White Birches, are in many sections being disfigured annually by a leaf-mining insect.

Bittersweet — See Celastrus

Black Haw — See *Viburnum prunifolium*

Bladdernut — See Staphylea

Bluebeard — See Caryopteris

Blueberry — See Vaccinium

Boxwood — See Buxus

Broom — See Cytisus and Genista

Bruckenthalia spiculifolia Spikeheath

A heather-like, rock-garden plant with ten-inch stems and bell-shaped, pink flowers in summer.

Buckthorn — See Hippophae and Rhamnus

BUDDLEIA ALTERNIFOLIA Hardy Buddleia

An exceptionally hardy, tall, loose, deciduous shrub. Because of its habit of bearing lilac-purple flower clusters in June on yard-long, pendulous sprays of wood of the previous season, this plant at once becomes separated in cultivation from the other top-tender, semi-herbaceous species. It does well on light, dry soils, and will withstand considerable shade, but will not flower profusely in shady situations. Best if pruned just after flowering, as are Spireas.

Buddleia Davidi var. nanhoensis

A somewhat dwarf and late-flowering variety for use where the species is top-hardy and severe spring pruning is not practiced.

BUDDLEIA DAVIDI var. VEITCHIANA Veitch Butterfly Bush

A "die-back", deciduous shrub over most of New England. Its ability to rise from the ground each spring to form a broad, symmetrical bush with tapering clusters of mauve, yellow-eyed flowers terminating its branchlets indicates its garden association as a background plant for the herbaceous border. Even where not killed back in winter, its garden value is enhanced by pruning to the ground each spring. Its flowers appear in August when few other woody plants are in bloom.

BUDDLEIA, "ISLE DE FRANCE"

Differs from *B. Davidi* in that spikes are somewhat longer, and of dark claret-purple flowers. Reported by some to be more top-hardy. Here, too, is a plant which will benefit by being cut down to the ground each spring.

Burningbush — See *Evonymus europaea*

Bushclover — See Lespedeza

Buttonbush — See Cephalanthus

Buxus microphylla var. koreana

A compact, broad-leaved, evergreen shrub from the Orient. With an ultimate height of about two feet, this variety is reputed to be the hardiest of the Boxes. As seen in cultivation in the North, it is less attractive than the more tender European garden forms.

Buxus sempervirens BOX

A traditional plant of European gardens which came to America as part of the life and culture of the early settlers. A formal, slow-growing, evergreen bush or small tree which has not proved generally satisfactory in New England except in more temperate areas near the sea. It has persisted in the North chiefly in the form, var. **suffruticosa**, much used as a small plant for edging beds. For inland New England the Box has given way to various forms of the Yew.

Callicarpa dichotoma (*C. purpurea*) CHINESE BEAUTYBERRY

A hardier, more widely distributed species than *C. japonica*, having smaller fruits which are eaten by birds.

CALLICARPA JAPONICA JAPANESE BEAUTYBERRY

A "die-back" shrub which comes from the root each spring to form a round bush up to some three feet in height and spread. Its chief garden value lies in the late, small, pink or whitish flowers which are followed quickly and in profusion by relatively large, showy, violet berries in late autumn after leaves have fallen. Not a plant for positions of major importance.

CALLUNA VULGARIS HEATHER

An introduced plant of sentimental association which has the ability to establish itself on moist, sandy or peaty, eastern soils. In nature it will, in time, through habit and superficial winter injury, become a ragged, unkempt-appearing plant some three feet in height. In gardens it may, however, be kept in form by occasional cutting to the ground. Its garden value is brought out only by mass planting either of a collection of clonal forms or of large groups of identical forms. Heather seeds itself so freely that in massed plantings individual specimens of clonal varieties will soon be crowded out unless volunteer plants are promptly eradicated.

In addition to the purple-flowered type, there are many garden forms, a few of which are: Var. **ALBA** with white flowers; var. **ALPORTII** with carmine flowers, erect and vigorous; var. **CARNEA** with pink flowers; var. **cuprea** with yellow foliage which turns bronze; var. **HAMMONDII** with white flowers; var. **hirsuta** with gray woolly foliage; var. NANA, very dwarf in habit and moss-like in aspect; var. **RIGIDA**, of somewhat coarser texture and a tendency toward horizontal habit in main stems; var. **rubra** with rosy-carmine flowers.

Calophaca wolgarica BEAUTIFUL LENTIL

A procumbent or flopping, deciduous shrub to three feet, which has grayish-green leaves and bright-yellow, pea-shaped flowers in June or July. For the border or dry areas on banks or in very large rock gardens.

Calycanthus fertilis var. nanus DWARF SMOOTH SWEET SHRUB
A small deciduous shrub for the rock garden.

Calycanthus floridus CAROLINA ALLSPICE (COMMON SWEET SHRUB)
A large, coarse, leathery-leaved, deciduous shrub formerly much used in American gardens because of its inconspicuous, heavily scented flowers. Many plants so named in cultivation do not have flower fragrance because they are of another species, *C. fertilis*. There is need for propagators to go back to known true material for the purpose of making fragrant plants available. It does well in full sun or partial shade in rich, moist, but well-drained soil.

CAMPSIS RADICANS (*Bignonia r.*) (*Tecoma r.*) TRUMPETCREEPER
Normally a coarse, rapid-growing, deciduous vine with ability to climb by stem roots, and bothersome propensity for throwing up unwanted suckers from underground roots. The flowers of the type are orange and scarlet in terminal racemes from July to September. When grown on limited support and kept heavily pruned, it has definite garden value. There are several cultivated varieties based on floral color, such as var. **atropurpurea** (red) and var. **flava** (yellow); or on growth rate, such as var. **speciosa** which is smaller than the type. There are also desirable but less hardy hybrids with the Asiatic species, such as **C. Tagliabuana, "Mme. Galen."** Such forms are all easily propagated by root cuttings. It does well near the sea and is useful for wild spots or on very extensive supports.

Candytuft — See Iberis

Caragana arborescens var. nana DWARF SIBERIAN PEA-TREE
A stunted, contorted-branched form of a normally large shelter-belt plant for sandy soils. It can be used in the rock garden.

CARPINUS BETULUS var. FASTIGIATA PYRAMID HORNBEAM
One of the fastigiate varieties of the European Hornbeam, which in time builds up into a neat column, thus lending itself to the making of tall formal hedges. It is not too top-hardy on high, dry locations.

CARPINUS CAROLINIANA AMERICAN HORNBEAM
This native "Blue Beech" with its tough-wooded, fluted, blue-gray trunk and low, spreading head (twenty to thirty feet in height) with stratified branching can serve effectively as a specimen or in wood edges along roadsides. Its foliage, unlike that of the European species, puts on a scarlet or orange autumn show. It is most at home in a cool, moist soil.

Caryopteris incana COMMON BLUEBEARD
A "die-back" shrub which in New England seldom gets to more than two feet in height. It is valued for its lavender-blue flowers from August to November, and may best be used in the herbaceous border. The trade now offers this genus in blue, white, and pink forms.

Cassiope hypnoides
A tufted, prostrate, small-leaved, evergreen, alpine shrub for cool, moist soil and partial shade in the rock garden. Rare in cultivation and difficult to grow.

Cassiope tetragona

An erect species to some twelve inches, which has pinkish-white flowers. Like *C. hypnoides*, it is difficult but possible for the rock garden.

Ceanothus americanus NEW JERSEY TEA

An erect, deep-rooted, non-vigorous, two- to three-foot, deciduous native shrub which is covered with many small, slender-stalked clusters of whitish flowers from July to September. Suitable for massing on dry, sterile roadside areas in sun or light shade. Best transplanted while young.

CELASTRUS ORBICULATA (*C. articulata*) ORIENTAL BITTERSWEET

Of somewhat more sturdy and shrub-like habit than the native Bittersweet, this Asiatic species is of superior value only when used where severe pruning is to be practiced. If allowed to climb at will, the scattered axillary clusters of berries on pistillate plants will not become showy until after the fall of the leaves. Fruiting takes place on two-year wood.

CELASTRUS SCANDENS AMERICAN BITTERSWEET

Because of thinner, slightly less vigorous growth, and a habit of carrying its less-scattered berries in exposed terminal clusters, this native species seems better than *C. orbiculata* for use as a free, deciduous climber. As with the Oriental species, the berries are orange, breaking open to display crimson, persistent fruits which are eaten by ruffed grouse and pheasants.

Cephalanthus occidentalis COMMON BUTTONBUSH

A coarse, deciduous, native shrub of somewhat regular outline, found growing on the banks of streams and ponds. In the wild, it is attractive for its globose heads of white flowers from July to September. It is useful in proper situations for roadside or natural planting, but has little claim to a place in the garden.

CERCIDIPHYLLUM JAPONICUM KATSURA-TREE

A hardy, deciduous, Asiatic tree which, because of the quick branching of its short trunk, forms in age a broad, low head of little more than fifty feet in height. Its branchlets are fine in texture, and the leaves, resembling those of the native Redbud, change from purple when first unfolding, through green in summer, to yellow in autumn. A plant for specimen use. The more tender Chinese var. *sinicum* is to be avoided.

CERCIS CANADENSIS AMERICAN REDBUD (JUDAS-TREE)

Though tender while young, older plants of this small, native, deciduous tree are hardy in many places in New England. Its garden value lies in a late April or early May display of rosy-pink flowers at about the time its leaves are unfolding. Its bloom has been known to clash in gardens with that of color forms of *Cornus florida*. A plant for the roadside wood edge or large border. Var. **ALBA** with white flowers is a fine thing where hardy.

CHAENOMELES JAPONICA (*Cydonia Maulei*)
LESSER FLOWERING QUINCE

Low, neat, deciduous shrub which seldom becomes more than a yard in height. Its brick-red flowers, which open before the broad, coarsely toothed leaves in early spring, are followed by yellow, not very conspicuous fruits. It deserves wider use. Var. **alpina** with procumbent stems should have a place in bank plantings and rock gardens.

CHAENOMELES LAGENARIA (*Cydonia japonica*) FLOWERING QUINCE

This is the tall, spiny-branched, deciduous, early spring-flowering, old favorite known commonly as Japanese Quince. Its chief garden value is its

April or May crop of reddish-scarlet flowers, which together with Forsythia light up a dull, early spring landscape. Best in full sun. There are numerous cultivated varieties based on flower color, ranging from whitish through pink to red.

Chamaecyparis obtusa var. gracilis SLENDER HINOKI CYPRESS

A small, slow-growing, upright, evergreen tree of compact habit. Its dark foliage is arranged in hanging branchlets giving the plant that aspect popularly designated as "Japanese." Of limited usefulness, but worth mentioning because it is seemingly of greater hardiness than the type.

CHAMAECYPARIS OBTUSA var. NANA DWARF HINOKI CYPRESS

A slow-growing, contorted-branched, rounded, evergreen plant suitable for large rockeries, or as a substitute for Boxwood in certain situations.

CHAMAECYPARIS OBTUSA var. PYGMAEA PIGMY HINOKI CYPRESS

Because of extremely slow growth and low, horizontal, spreading habit, this evergreen plant would seem to have a place in the rockery or, in certain situations, in masses as a ground cover.

Chamaecyparis pisifera SAWARA CYPRESS

A tall-growing (one hundred feet at full maturity), loose-branched, evergreen tree which in the past has sometimes been forced into garden use as an inappropriate substitute for *Thuja occidentalis.* It probably has little garden value except as a large, open specimen with loose, horizontal branching and shaggy, reddish trunk.

Chamaecyparis pisifera var. filifera THREAD CYPRESS

Rather pleasing as a small plant but, like the type, becoming tall and ragged when older. There are a number of forms, probably the best of which is a dwarf plant of bushy habit (sub. var. NANA) which remains compact and carries on indefinitely the pleasing, thread-like appearance.

Chamaecyparis pisifera var. plumosa PLUME CYPRESS

A fine-leaved form usually seen in cultivation as a multiple-stemmed plant which soon becomes open and ragged unless subjected to severe clipping. It should not be used in limited areas, as has been the recent custom. When given room enough and kept to a single leader, it will make a large tree of the same open habit as the type. There are in cultivation a number of high-colored but rather banal forms of this variety.

Chamaedaphne calyculata LEATHERLEAF

A somewhat ragged, spreading, broad-leaved, evergreen shrub which has white but not too showy flowers in midspring. It is useful as a ground cover for fairly moist, sandy or peaty soils, especially if cut back to ground level every few years to insure dense, multiple branching.

Chaste-Tree — See Vitex

Cherry — See Prunus

Chiogenes hispidula CREEPING SNOWBERRY

A tiny, prostrate, spreading, broad-leaved, evergreen shrub with aromatic foliage and summer-borne white berries. Notoriously difficult in cultivation, it can be used only as limited ground cover or a rock-garden plant in moist, shady, acid locations.

CHIONANTHUS VIRGINICA WHITE FRINGE-TREE

A large deciduous shrub or small tree having, in May or June, hanging panicles of flowers which are followed in autumn, on the pistillate plants, by blue fruits. The flowers of the non-fruiting staminate plants are larger and are borne in larger clusters. It needs plenty of room, moist sandy soil, and full sun.

Chokeberry — See Aronia

Cinquefoil — See Potentilla

CLADRASTIS LUTEA YELLOW-WOOD

Growing upright to a height of some fifty feet, this native deciduous tree has a smooth gray bark, interesting compound foliage, and long panicles of white, fragrant, June-borne flowers to give it garden value. It seems to be more at home in deep, moist soil. In cultivation, it should be prevented while young from forming competing leaders which in subsequent development may cause structurally weak crotches in the main stem.

CLEMATIS

Because, under the severity of most northern winters, the tops of Clematis are killed, these quite arbitrarily scored selections have been made, for the most part, from among those varieties which flower on the wood of the current season. By making use of this fortunate property of certain species, the New England gardener may insure Clematis flowers for his garden. To gain this end, however, he must sacrifice early bloom and be content with summer and autumn flowering.

For culture, the hybrids need good drainage, no drought, ample organic food in a non-acid root run, support for their tops, and shade for their crowns. Exceptionally well situated is that Clematis which is planted with its roots in the shade of a coarse shrub, up through the branches of which its top may clamber to obtain for its flowers a coveted place in the sun. Own-root plants are superior to grafts.

CLEMATIS HYBRIDS

"CRIMSON KING" — name suggestive of flower quality; most difficult of cultivation. **"DUCHESS OF ALBANY"** — hybrid of *C. texensis* (which see), with trumpet-shaped crimson and white flowers. **"GYPSY QUEEN"** — flowers of richer purple than Jackman's Clematis. **"JACKMANI"** — very common, easily grown hybrid with four- to six-inch violet-purple flowers. A white form is sometimes listed. **"JOUINIANA"** — rampant growth to ten to twelve feet. Bell-shaped, inch-wide, lavender flowers in profusion in autumn. Species-like in garden effect. **"HENRYI"** — enormous white flowers in summer. **"MME. EDOUARD ANDRE"** — purplish-red flowers. **"MRS. CHOLMONDELEY"** — light blue flowers. **"NELLIE MOSER"** — mauve flowers with red band down the center of each petal. **"PRINS HENDRIK"** — azure-blue flowers.

CLEMATIS MACROPETALA

Azure-blue, unusual-shaped, two-inch flowers. Exceptionally hardy.

CLEMATIS MONTANA var. RUBENS PINK MOUNTAIN CLEMATIS

A fine thing of doubtful value for all sections because it flowers on old wood. Excellent rampant sort in protected spots or in warmer sections near the sea.

CLEMATIS PANICULATA SWEET AUTUMN CLEMATIS

Well known for its September masses of fragrant white flowers followed by plumed fruits. It can be used for ground cover in somewhat shaded spots, is indifferent to soil conditions, and almost unfailing in its good garden behavior.

CLEMATIS TANGUTICA GOLDEN CLEMATIS

Bright yellow, lantern-shaped flowers in early autumn, followed by attractive masses of plumed seeds. It comes up each year with many relatively short stems, and is best if planted to fall forward over a retaining wall or on a bank.

CLEMATIS TEXENSIS (*C. coccinea*) SCARLET CLEMATIS

Scarlet to rose-pink, urn-shaped flowers in June and occasionally thereafter until frost. Of high garden value as a graceful, non-rampant climber.

Clematis virginiana VIRGIN'S BOWER

A rampant native species adapted to a wild, somewhat shaded, landscape where it may clamber about on near-by woody plants. White flowers from July to September. In gardens it is inferior to *C. paniculata.*

CLEMATIS VITICELLA var. KERMESINA

Wine-red, two-inch flowers on a thrifty, medium-textured plant from June to August. Markham reports maximum height of eight feet.

Clerodendron trichotomum HARLEQUIN GLORYBOWER

A course, suckering shrub for planting in large, wild masses in warmer sections or elsewhere where it can sprout up unchecked if frozen down. Not valuable as an individual plant. The late, whitish, fragrant flowers are followed in early autumn by blue-black fruits set off by a background of persistent crimson flower parts.

Clethra acuminata CINNAMON CLETHRA

A larger, more vigorous, deciduous shrub than *C. alnifolia*, with larger flower clusters from July to September.

CLETHRA ALNIFOLIA SWEET PEPPERBUSH

A medium to large, upright, native, deciduous shrub of moist places in sun or partial shade. Fragrant white flowers in erect panicled racemes from July to September. Foliage yellow in autumn. A plant of considerable value for certain phases of wild roadside development. Var. **rosea** has pinkish flowers.

Clethra barbinervis TREE CLETHRA

A still larger Clethra reaching as much as forty feet in height. Flower clusters large and fragrant. Stems and framework of plant interesting in winter.

Clinopodium georgianum (*C. carolinianum*)

An eighteen-inch, free-branching, evergreen shrub with pink, mint-like flowers from September on. An easily transplanted rock-garden plant.

COMPTONIA ASPLENIIFOLIA (*Myrica aspleniifolia*) SWEET-FERN

A loose-branched, aromatic, deciduous shrub with dark, fern-like leaves, which has the ability to advance quickly over raw roadside cuts in dry, subneutral, sandy or gravelly soils and pile up a pleasing, graceful, ground-covering mass to a height of some five feet.

Coralberry — See *Symphoricarpus orbiculatus*

Corema Conradii BROOM-CROWBERRY

A fine-branched, heath-like, evergreen plant which is found in nature on sandy or rocky wastes. In the wild it usually becomes much broader than its twelve inches of height. Its male flowers have showy purple parts. It will grow in the rock garden in situations suitable for *Arctostaphylos uva-ursi.*

Cork-Tree — See Phellodendron

CORNUS ALBA var. SIBIRICA CORAL DOGWOOD
A medium-textured, deciduous shrub which is planted chiefly for the winter effect of its coral-red young branches. The small, white flowers of May are followed in autumn by whitish fruits. It is indifferent as to soil and will stand some shade.

CORNUS ALTERNIFOLIA PAGODA DOGWOOD
A large deciduous shrub or small tree with spreading branches in stratified arrangement. In autumn it has dark-blue fruits on red stems. A plant to fit into the edges of woods.

Cornus canadensis BUNCHBERRY
A Dogwood of but a few inches in height, which spreads in cold, shaded, acid, woodland soils by an underground rootstock. It has its leaves in whorls and follows its greenish flowers by red berries. Of limited, specialized interest because of exacting cultural requirements.

CORNUS FLORIDA FLOWERING DOGWOOD
A familiar, small, multiple-branched, deciduous tree of southern New England. It is difficult to transplant as an older plant, and in the wild is best moved to the same sort of soil and environmental conditions as those of its original site. There are several varieties in cultivation, among the most useful of which are var. **RUBRA** with red or pink flowers, and var. **XANTHOCARPA** with yellow fruits.

CORNUS KOUSA JAPANESE FLOWERING DOGWOOD
A small, deciduous, Asiatic tree or large shrub which seems to have no other positive garden value than the ability to prolong the blooming season of the Flowering Dogwood.

CORNUS MAS CORNELIAN CHERRY
Small deciduous tree or large shrub, much planted in the past for its show of yellow flowers before the leaves in early spring; useful, also, because of its long-persistent green leaves and early autumn crop of edible scarlet fruits. Like other Dogwoods, it can be made to appear at home in semi-wild plantings.

CORNUS RACEMOSA (*C. paniculata*) GRAY DOGWOOD
Large, spreading, deciduous shrub of regular outline, which will sucker freely to cover considerable areas. June and July flowers are followed in autumn by a mass of whitish fruits on red stems. Its ripe berries are quickly removed by birds. A useful plant for roadside or large, wild, bank planting.

CORNUS STOLONIFERA RED-OZIER DOGWOOD
A spreading, suckering, ten-foot shrub which, like *C. alba*, has blood-red branchlets, white flowers in May, and white fruits. The winter effect of its colored stems makes it suitable for planting large roadside banks. Var. **flaviramea**, GOLDEN-TWIG DOGWOOD, has yellow stems.

CORYLOPSIS PAUCIFLORA BUTTERCUP WINTERHAZEL
A spreading-branched, deciduous shrub with an ultimate height of perhaps twelve feet. Valuable for its March or April yellow flowers which appear before the unfolding of the interesting, rounded leaves. Not fully hardy or sure of flowering except on Cape Cod and in southeastern sections of New England.

CORYLUS AVELLANA var. CONTORTA TWISTED STEM FILBERT

A somewhat curious but not grotesque, spiral-stemmed form of the European Hazelnut, which builds up into a rather broad, stocky, deciduous shrub, quite suitable for the top of a very large rockery. There are numerous other varieties and hybrids of this species, which was much used in the past for ornament but is now interesting because of edible nuts.

Corylus Colurna TURKISH HAZEL

A thick-limbed, eighty-foot, deciduous tree of pyramidal habit, having gray, furrowed bark and smooth, rounded leaves. It does not transplant easily in larger sizes.

Corylus cornuta (*C. rostrata*) BEAKED HAZELNUT

A nine-foot, free-suckering, native, deciduous shrub with velvety leaves and interesting beaked fruits. It has a use as a tall, thicket-forming ground cover for roadside development.

Cotinus coggygria (*Rhus cotinus*) COMMON SMOKE-TREE

A large, coarse, deciduous shrub which was much used in old-time gardens as a specimen plant. It owes its garden value and common name to the cloud-like appearance of its mass of plumy-fruiting parts in August and September; also to the yellow or purple autumn leaf tints. It can be used toward the back of deep, high borders. Var. **purpureus** shows purple in young foliage and flower parts.

COTONEASTER

Because of a rigorous climate, most inland New England gardens cannot hope to contain all of the numerous expressions of this group of deciduous and evergreen shrubs, or sometimes small trees. Despite the fact that the Cotoneasters are more at home in warmer temperate sections, careful selection can determine a few adaptable deciduous or semi-evergreen forms which can serve to display the wide range of habit, fruiting qualities, and garden uses of their genus. Such a selection is herewith attempted. Cotoneasters are all best handled as very small plants or from pots.

COTONEASTER ADPRESSA CREEPING COTONEASTER

A prostrate, creeping, deciduous shrub which can spread out to form a mat yards across but with a height of seldom more than a foot or so. The bright red fruits of early autumn are larger but fewer than those of *C. horizontalis.* A plant for the larger rockery or for somewhat sheltered banks.

COTONEASTER APICULATA

A hardy, horizontal-branched, deciduous shrub which in late autumn carries a profusion of exceptionally large, persistent, red fruits. While possibly less interesting in branching than *C. horizontalis*, it is definitely more reliable than that species and superior for large-scale rock or bank planting.

COTONEASTER DAMMERI var. RADICANS (*C. humifusa*)

A fine-wooded, prostrate-branched shrub which is able to spread out over a considerable area by the simple process of rooting down as it goes. In warmer areas it retains its small, dark, glossy foliage throughout the winter as a background for the small red berries. A fine ground-cover or rockery plant where hardy, or where protected by snow of some depth.

COTONEASTER DIELSIANA DIELS COTONEASTER

A loose-growing, deciduous, six-foot shrub with arching branches, grayish foliage, and small scarlet fruits. A plant which can be used in groupings or for making unpruned, informal hedges. Varieties **major** and **elegans** are of little garden interest beyond the fact that their foliage is respectively larger and smaller than the type.

COTONEASTER DIVARICATA SPREADING COTONEASTER

In habit, much like *C. Dielsiana* but with darker green foliage and slightly larger, more prominent, red fruits. Also useful for grouping or for informal hedge making.

COTONEASTER FOVEOLATA

A vigorous, stout-branched, deciduous shrub growing up to some ten feet in height. Its general aspect, together with autumn properties of red or orange foliage and black fruits, puts its garden value at about that of some of the Viburnums.

COTONEASTER HORIZONTALIS ROCK COTONEASTER

A rather well-known semi-evergreen species which is much liked because of the regular, two-ranked arrangement of the branchlets on its horizontally reaching main stems, glossy foliage, and small but numerous, late, red fruits. Against all of these fine qualities lies the lack of true top-hardiness so necessary if full garden value is to be brought out. It is now losing out to *C. apiculata* for use in large-scale plantings. The var. **PERPUSILLA**, with larger and more interesting foliage, is now preferred to the type.

COTONEASTER HUPEHENSIS HUPEH COTONEASTER

A fine, six-foot, deciduous shrub which, in addition to the pleasing arch of its branches, the purplish sheen of its foliage, the early autumn show of its brilliant red fruit, and the later yellowing of its leaves, is valuable because of its May-borne clusters of white flowers. Such a plant is useful even though the flowers do throw off an odor which has been considered by some to be distasteful.

COTONEASTER MICROPHYLLA var. THYMIFOLIA THYME ROCKSPRAY

A low, spreading, evergreen, rock-garden shrub which has small shiny leaves, tiny pinkish flowers in clusters in the spring, and scarlet berries in autumn. It will need protection to be evergreen inland.

COTONEASTER RACEMIFLORA var. SOONGORICA

A loose, graceful, slender-branched, six-foot, deciduous shrub with gray foliage, of value chiefly because of its numerous red or coral fruits. Rated by some as the best species of its habit; considered by others to be difficult of cultivation.

Cotoneaster salicifolia var. floccosa

A tender, semi-evergreen shrub which is not satisfactory in New England except in warmer sections near the sea. When happy, it becomes a graceful plant with narrow shining leaves and the ability to put on a startling late-autumn fruiting display.

Crabapple — See Malus

Cranberry — See *Vaccinium macrocarpum*

Cranberry-Bush — See *Viburnum trilobum*

Crataegus

In New England gardening, the trend seems to be away from the use of Thorns and in their place to take up the better forms of the flowering Crabapples. Though this last group, especially some of the native sorts, are not free from disease, they are in that respect much more satisfactory in cultivation than Hawthorns. Hence, the few species and varieties of Crataegus suggested here.

CRATAEGUS CRUS-GALLI Cockspur Thorn

An old-time, thorny, hedge plant which, when grown as an individual specimen, can build up into a tree some thirty feet in height, with late white flowers, glossy foliage turning orange and scarlet in autumn, and persistent red fruits.

CRATAEGUS NITIDA Glossy Hawthorn

A tree of some thirty feet with glossy foliage which, after turning orange or scarlet in autumn, drops to leave a show of persistent red fruits.

CRATAEGUS OXYACANTHA English Hawthorn

A familiar, dense-headed, spiny-branched plant with small leaves, white flowers, and persistent red fruits. The most common Hawthorn in eastern nurseries, and sometimes offered in double pink-flowering forms as well as the usual double red var. PAULII. It is notoriously difficult to transplant in larger sizes.

Crataegus persistens

A small tree similar to the Cockspur Thorn, but about one-third as large. Its leaves and red fruits are relatively long persistent.

CRATAEGUS PHAENOPYRUM (*C. cordata*) Washington Thorn

A long-spined, dense-headed, deciduous tree to some thirty feet. This species grows as well as any Thorn and displays clusters of scarlet berries in autumn against orange or scarlet foliage.

Crowberry — See Corema and Empetrum

Cypress — See Chamaecyparis

Cytisus Ardoinii

A procumbent or flopping, somewhat tender Broom which bears golden-yellow flowers in May or June. Adaptable for dry, sheltered positions in the rockery.

Cytisus decumbens

A prostrate, sessile-leaved Broom which has bright yellow, pea-shaped flowers in May or June. Where hardy, it will form a mat some eight inches in height. A rockery plant.

X CYTISUS KEWENSIS

A procumbent Broom with creamy-white to pale-yellow flowers, which forms mats of about one foot in thickness. A surprisingly hardy rock-garden plant.

Cytisus scoparius Scotch Broom

An upright-branched, slender, green-stemmed, somewhat exotic-appearing deciduous shrub which has become naturalized in coastal areas, often to the detriment of the native flora. Where hardy it shows its yellow, pea-shaped flowers in May, long-persistent foliage, and a distinct winter effect because of its stem coloration. Interest in true conservation will discourage its broad use as a ground-cover plant. Var. **Andreanus** has yellow flowers with purple wings.

Daboecia cantabrica Irish Heath

A purple-flowered, top-tender, heath-like plant which is suitable for sandy or peaty spots in the warmer rock garden. Forms which have white or two-toned floral color are often seen.

Daphne Blagayana BALKAN DAPHNE

A one-foot, evergreen shrub which has creamy-white fragrant flowers in early spring. A relatively rare rock-garden plant.

DAPHNE CNEORUM ROSE DAPHNE

The species which typifies Daphne in the public mind. Though quite at home in inland New England, it has proved difficult in sections of droughty, sandy soil, which have long, hot, dry periods in the summer. Var. **ALBA** has white flowers.

DAPHNE GENKWA LILAC DAPHNE

A slender-branched, deciduous shrub which displays clusters of silky, lilac, scentless flowers in March or early April before the unfolding of its leaves. Because of a far-flung root system, this species, like other Daphnes, resents transplanting after once becoming well established. Not hardy; or at best, a plant for the protected rockery in cold, inland sections.

DAPHNE MEZEREUM FEBRUARY DAPHNE

Stocky, upright-branched, deciduous shrub which in late March or early April carries fragrant, lilac-purple flowers before the leaves. In late summer appear clusters of scarlet fruit which are sometimes hidden by foliage and new growth, or may be removed quickly by birds. A stiff, three-foot shrub for high, well-drained soil. It does well in partial shade. In some situations in full sun, it becomes unsightly in late summer because of premature loss of foliage. Var. **ALBA** is white flowered.

DAPHNE PETRAEA TYROL DAPHNE

A pleasing, six-inch, evergreen shrub which has terminal clusters of fragrant, rose-colored flowers in June. Being a plant of European alpine rock crevices, its far-reaching root system makes it a difficult thing to handle unless grafted on roots of some more normal-rooted species. A rare plant for the rock garden.

Decumaria barbara

A slow-growing, deciduous, root-climber which has glossy foliage and feathery clusters of fragrant white flowers in May and June. Will substitute for *Hydrangea petiolaris* as a climber or cover for rocks in shady woodland situations where the air is moist.

DEUTZIA

Because of perennial winter injury and an unfortunate stiffness of adult aspect, this group has, in New England, lost most of whatever popularity it may have enjoyed in the past. However, when kept young by the proper sort of pruning program, the following species will prove themselves to be worthy of attention in warmer areas.

DEUTZIA GRACILIS SLENDER DEUTZIA

Though capable of much taller growth, this relatively hardy, dull-leaved species is usually met with in gardens as a two- to three-foot, bushy, deciduous shrub with thin, upright stems on which the white flowers are borne in upright clusters in May. It is forced easily.

X DEUTZIA LEMOINEI, "BOULE DE NEIGE"

A garden hybrid which has a slightly greater growth rate and is somewhat more open in habit than *D. gracilis*. In bloom in June, it is outstanding because of prominent dense clusters of relatively large, white flowers.

X Deutzia rosea var. campanulata BELLFLOWER

A hybrid of *D. gracilis* which has larger, more open flowers than the parent species. The growth rate and habit of both are much the same.

Deutzia scabra var. Watereri

A straight-stemmed, rough-leaved, deciduous shrub which is capable of growing to a height of seven or eight feet. Its single white flowers are carmine outside and open in late May or early June. Probably the hardiest of the taller-growing Deutzias.

Diapensia lapponica

A small-leaved, evergreen shrub of alpine summits which develops few-inch tufts and has white flowers in early summer. Adaptable for some rock gardens.

DIERVILLA FLORIDA var. VENUSTA (*Weigela rosea venusta*) PINK WEIGELA

The hardier and more desirable form of the well-known, old-fashioned Pink Weigela, which makes a vigorous, symmetrical, deciduous shrub up to ten feet or so in height, and in June is covered with rosy-pink flowers. It has given way recently to the somewhat hardier and more graceful *Kolkwitzia amabilis*. All members of this group have a number of insect enemies and also are apt to be somewhat unkempt in appearance after the passing of the flowers.

X Diervilla hybrida WEIGELA

Numerous crosses of *Diervilla florida* with other species have given some fine, June-flowering garden shrubs which generally are not fully top-hardy throughout New England. The full color range of these varieties is given by the following varieties: "**Abel Carriere**" has purple-carmine buds which open into rose-carmine flowers; "**Candida**," where perfectly hardy, is one of the best white-flowering varieties; "**Congo**" has freely borne, purplish-crimson flowers; "**Eva Rathke**" makes a rather scraggly, upright plant covered by deep carmine-red flowers in late May or early June.

Diervilla Lonicera DWARF BUSH-HONEYSUCKLE

A two- to three-foot, native, deciduous shrub of somewhat herb-like aspect which, when planted in masses, can light up open, dry, rocky roadside areas with its yellow midsummer flowers.

Diervilla praecox EARLY WEIGELA

A somewhat smaller and less ornamental shrub than *D. florida* var. *venusta*, which is included here because of its early-May, showy, purplish-pink or rose-carmine flowers.

Diervilla sessilifolia SOUTHERN BUSH-HONEYSUCKLE

A native of the upper South which is suitable for mass planting on rough banks. More gross in every detail than *D. Lonicera*.

DIRCA PALUSTRIS LEATHERWOOD

A slow-growing, medium-sized, pliable-stemmed, native, deciduous shrub of open, sunny areas. Garden value is based on its early, pale-yellow flowers. Adapted to roadside or other natural development.

Dogwood — See Cornus

DRYAS DRUMMONDII

A prostrate, creeping, evergreen shrub with leaves which are dark green above and white, woolly beneath. When happy, it spreads out to form a rock-garden ground cover from which in spring rise numerous yellowish flowers.

DRYAS OCTOPETALA

A species which is similar to the above except for its white flowers and smaller leaves. Of the two, this species is more widely distributed in gardens.

Dutchman's Pipe — See Aristolochia

Elaeagnus augustifolia RUSSIAN OLIVE

Large, coarse, gray-twigged, silvery-leaved, deciduous shrub up to some twenty feet in height. Of little garden value until it has reached sufficient size to produce masses of inconspicuous fragrant flowers, which in autumn are followed by highly ornamental masses of fruit. It has little, if any, value as a small shrub or in a small-scale planting, and is somewhat difficult to transplant. This is the hardiest species of a large ornamental genus.

Elderberry — See Sambucus

Elm — See Ulmus

ELSHOLTZIA STAUNTONI

A "die-back" shrub which rises from the ground each spring to some two or three feet to show its prominent, one-sided spikes of lilac-purple flowers in early autumn. It can be used in an herbaceous border or in the interstices of large and more permanent woody planting.

Empetrum nigrum CROWBERRY

A ten-inch, spreading, evergreen, heather-like shrub having narrow leaves, small purplish flowers, and conspicuous black fruits. Like other native shrubs of this sort, it resents being taken from the wild in the form of mature plants. When handled as very young plants in pots, it can be made to grow in the rock garden.

English Ivy — See Hedera

ENKIANTHUS CAMPANULATUS REDVEIN ENKIANTHUS

Tall, somewhat stiff, deciduous shrub. Azalea-like in aspect, its garden value lies in its clusters of creamy-yellow, bell-shaped flowers which in May hang from stiff rising branches much after the manner of those of *Berberis amurensis* var. *japonica*. Its autumn show of brilliant red foliage is also worth while. Culture is about like that required for native Azaleas.

ENKIANTHUS PERULATUS WHITE ENKIANTHUS

A shorter, fuller shrub than *E. campanulatus*, which bears white flowers in May and has yellowish autumn coloration of its deciduous foliage.

Ephedra distachya COMMON JOINT-FIR

An exotic, green-stemmed, scale-leaved, procumbent shrub of arid regions which, though out of character in this region, can add interest to a rock-garden collection. Both sexes must be present if the red, berry-like fruits are to be expected to form.

Ephedra equisetina

An upright species which in appearance more nearly resembles the Horsetail from which it takes its name. Of interest in rock gardening.

EPIGAEA REPENS TRAILING ARBUTUS

A familiar plant which can be used as a limited ground cover in light, sour soils in open woodland areas or in the rock garden. It should not be torn from the wild but introduced into the garden as nursery-propagated plants. It is best handled as small plants from pots.

ERICA CARNEA SPRING HEATH

A spreading-branched plant which, like other Ericas here mentioned, is somewhat more pleasant in foliage aspect than Calluna. This species grows a foot or more in height and displays its rosy-red flowers in very early spring. This and other species of Erica, not being reliably top-hardy, are in inland New England confined in use to specimens in the sheltered rock garden.

Erica Tetralix CROSS-LEAF HEATH

This is the straggly Erica which has become naturalized in moist land on Cape Cod. Its clusters of rosy flowers appear from June to the end of the season. It can be used in sour, wet spots in the rock garden.

ERICA VAGANS CORNISH HEATH

A somewhat tender-topped Heath which, after being frozen, can come back from the base to a height of some fifteen inches. Its pinkish flowers are borne in narrow, six-inch spikes. Like other Heaths and Heathers, its flower parts are persistent. Var. KEVERNENSIS is a dwarf form. Various other varieties based on floral color are also offered.

Escallonia virgata

A low-spreading, deciduous shrub which is the hardiest representative of its genus. A leafy, white-flowered plant for the large rockery in warmer sections.

EVONYMUS ALATA WINGED SPINDLEWOOD

A tall, broad, deciduous shrub which in old age intermingles its outer stratified branches in a pleasant-appearing, symmetrically rounded bush some eight or ten feet through. The corky wings projecting from the surfaces of the young shoots and the red fruits are interesting details made obscure by the foliage as the plant is seen in gross aspect. Its foliage turns a fiery red in autumn, later dropping to reveal for the winter a most interesting plant skeleton. Being fine rooted, adult plants can be shifted safely at any season of the year. So finely compact are the root systems that adult plants transplanted into heavy soil have been known to starve rather than reach out new roots into the strange medium with which they have been surrounded. Plants grown to maturity in the open may be shifted into shady situations for screen purposes. Var. COMPACTA, DWARF WINGED SPINDLEWOOD, is a compact, symmetrical, slow-growing, deciduous shrub which is fine in its own right as a hedge or specimen plant but does not show the interesting stratification of branches characteristic of the type. Its foliage shows high coloration in autumn.

EVONYMUS EUROPAEA EUROPEAN BURNINGBUSH

A large, deciduous shrub or small tree growing to a height of twenty feet. Its chief garden value lies in the autumn show of pink or red fruits which break open to display orange seeds after the seasonably crimson leaves have fallen. A plant which naturalizes readily.

Evonymus nana

A flopping deciduous shrub with greenish, angled branches, narrow leaves, and pink fruits. It can be planted on banks or to fall forward at the top of a large rockery.

EVONYMUS OBOVATA RUNNING EUONYMUS

A deciduous shrub which seldom becomes over one foot in height but runs along in reasonably moist soil, rooting as it goes. A mat-forming plant which in autumn carries attractive pink or scarlet fruits. A thin ground cover which can withstand considerable shade.

EVONYMUS RADICANS Wintercreeper

An evergreen, trailing or root-climbing species which varies in cultivation in much the same manner as does the so-called English Ivy. There are climbing forms which show variation in vegetative characters such as leaf shape. Other garden forms have arisen from the vegetative propagation of the gross fruit-bearing branches. There are variegated leaf varieties which have resulted from physiological upset. This, the type, having leaves about an inch long and making a good ground cover or root climber for flat masonry surfaces, stands shade quite well and is indifferent as to soil requirements. All forms of this species must be protected against scale insects. Var. **ACUTA**, Sharp-leaf Wintercreeper, is a vegetative variant of the type, having pointed leaves. Var. **CARRIEREI**, Glossy Wintercreeper, is a fruiting form which has more pointed, glossier foliage, and as it grows older remains more shrub-like than var. *vegeta* but is much inferior to it in profusion of fruit. Var. **COLORATA** is another vegetative climbing form resembling var. *acuta* but considered superior to it because of bright-red, winter foliage coloration. It is excellent for ground cover and will withstand shade but shows poorer winter color in such a situation. It does not produce climbing roots as readily as the type. Var. **MINIMA**, Baby Wintercreeper, is a somewhat miniature vegetative form of limited growth with leaves a half-inch or so long, useful for ground cover or rockery. It does not climb readily. Like the type, its rarely borne fruits form on coarse, large-leaved shoots. It is often confused with the still smaller-leaved var. *kewensis*. Var. **VEGETA**, Bigleaf Wintercreeper, is a shrub-like form having large, round, thick, evergreen leaves and in autumn pink and orange Bittersweet-like fruits in profusion. Since it represents the vegetatively propagated fruiting wood of the type, it had better be kept in the open away from high support if continued shrubby habit is desired. In the presence of something to which to cling, vegetative climbing growth will be resumed until the limit of the available support has been reached.

EVONYMUS YEDOENSIS Yeddo Euonymus

A heavy-branched, upright, deciduous shrub with large leaves which take on a high autumn color, and with pale-pink fruits and orange seeds. Rated as one of the better deciduous shrubby species.

EXOCHORDA GIRALDII Redbud Pearl-Bush

A large, spreading, upright, thin-stemmed, deciduous shrub which is valued chiefly for its pure-white flowers in May, but because of its bright green leaves maintains a suitable appearance during the rest of the growing season. A plant for large borders and full sun. Var. **WILSONII** is reported to be more vigorous and floriferous than the type.

FAGUS GRANDIFOLIA (*F. americana*) American Beech

The native beech which, though familiar to everyone, is seldom offered by the trade.

Fagus sylvatica European Beech

Like all plants which have been long in cultivation, this species has numerous garden forms, a few of which are: Var. **atropunicea**, the well-known purple beech; var. **FASTIGIATA** which grows up in pleasing and useful columnar form; and var. **pendula**, the well-known weeping form, which comes also in a purple-leaved variety of doubtful esthetic value.

Filbert — See Corylus

Fir — See Abies and Pseudotsuga

Fleecevine — See Polygonum

X FORSYTHIA INTERMEDIA var. PRIMULINA Primrose Forsythia

A variety worth consideration because of its fewer, paler flowers which are borne in such a manner that its garden effect is somewhat less violent than some of the more floriferous species and varieties.

X FORSYTHIA INTERMEDIA var. SPECTABILIS Showy Border Forsythia

This variety, with its numerous bright yellow, early spring flowers crowded on upright stems, is perhaps the most eye-smiting of all the Forsythias and, judged on this basis alone, can be considered the best.

Forsythia ovata Korean Forsythia

A slower-growing, hardier species of distinctly inferior garden value except for its possible earlier flowering in those sections where other Forsythias are hardy. However, it can be recommended for cold, inland areas where buds of the more common species and varieties blast during the winter.

Forsythia suspensa var. Sieboldii Weeping Forsythia

Pendulous or trailing-branched shrub suitable for covering banks or for training up on walls as a vine.

FOTHERGILLA GARDENI Dwarf Fothergilla

Slow-growing, symmetrical, low, deciduous shrub which is covered in spring with spikes of white flowers. For garden purposes it may be considered to be a dwarf form of *F. monticola*. Suitable for the large rock garden.

FOTHERGILLA MONTICOLA Alabama Fothergilla

While considered by some to be indistinct from *F. major*, plants grown under this name are of shorter stature, more spreading habit, and yield slightly larger flower spikes. This inhabitant of peaty soils is slow of growth, regular in outline, and in foliage aspect somewhat suggestive of the Witch-Hazel, to which it is related. Its spikes of white flowers are borne on a framework of stiff, gaunt branches in May, just as the leaves are beginning to unfold. In autumn appears the brilliant crimson or yellow foliage color. For best effect it should stand alone.

Franklinia — See Gordonia

Fraxinus americana White Ash

A familiar, quick-growing, native, deciduous shrub of moist woodland, which is prone to volunteer in shrub borders or other disturbed areas of soil. Under wild conditions it can become a timber tree one hundred feet or more in height. It is, however, of rather coarse texture for street or home-grounds use, and is subject to attack by scale insects.

Fringe-Tree — See Chionanthus

GAULTHERIA PROCUMBENS Wintergreen

A familiar plant which is native to woods and open lands, and has a definite place in the wild garden or rockery.

Gaylussacia baccata (*G. resinosa*) Black Huckleberry

A twiggy, deciduous shrub up to three feet, which in nature is variable in stature and technical details, as well as in its ability to be at home on acid soils, both dry and wet. It has value as rough ground cover for roadside plantings.

GAYLUSSACIA BRACHYCERA Box Huckleberry

A low, spreading, evergreen plant which can, in reasonably moist, sandy or peaty soil, reach out to cover large areas with a mass of Box-like foliage. It can withstand light shade and serve as a rockery plant.

Genista hispanica Spanish Broom

A top-tender, much-branched, slightly spiny, half-evergreen shrub which has terminal clusters of yellow flowers in May or June. It may be looked upon as a plant for dry, sheltered rock gardens in warmer sections.

GENISTA PILOSA Silky-leaf Broom

A somewhat hardier, prostrate shrub with greenish stems which root down as they extend. Its dark foliage and yellow flowers from May to July make it an interesting plant for well-drained locations in the rock garden.

GENISTA SAGITTALIS

Another low, mat-forming shrub which has winged stems, rounded leaves, and yellow flowers in June or July. A reasonably hardy rock-garden plant.

Germander — See Teucrium

GINKGO BILOBA Maidenhair Tree

Classed botanically with the evergreens, this relic species, preserved in Oriental temple grounds, though awkward appearing while young, in time can build up into a broad-headed, interesting-textured deciduous specimen some hundred and twenty feet tall. Its common name aptly characterizes its foliage. Because of the untidiness and offensive smell occasioned by the fall of the fruits in autumn, prudence dictates the use of the male form only. Var. FASTIGIATA is a narrow, pyramidal tree of upright branching which lacks the fine texture and full-bodied effect of *Quercus robur* var. *fastigiata*, or of several other columnar forms.

Gleditsia triacanthos var. inermis Thornless Honey-Locust

This is a thornless form of the well-known spiny-stemmed, usually multiple-branched, type plant.

Goldenrain-Tree — See Koelreuteria

GORDONIA ALATAMAHA Franklinia

In the North, usually a gaunt shrub with large, shining, deciduous leaves and pure-white flowers in late September or early October. It has romantic interest because of association with John Bartram, and its subsequent disappearance from the section of its discovery. Except south of Boston, it must be grown in sheltered spots. Because of its lanky appearance, it can well be pushed into a mixed planting in moist or peaty soil. If pruned severely in spring, it will grow bulky.

Grape — See Vitis

Gymnocladus dioeca Kentucky Coffee-Tree

A tall, bare-boled, few-branched, deciduous tree with compound leaves and large, flattened seed pods. Not too valuable as a lawn or street tree because of its liking for moist soil and the large amount of litter which it drops.

HALESIA MONTICOLA Mountain Silverbell

While this plant becomes a large tree in its native mountains farther south, in cold northern gardens it is usually seen as, or had best be pruned to, a large, open, gray-barked, deciduous shrub. When so grown, the large clusters of hanging, bell-shaped flowers in May, followed by dry, winged fruits, give it definite garden value. Here is a plant for backs of large borders and edges of woodlands. Var. **rosea** has pleasing, pale-rose flowers but, unfortunately, seems to be less hardy in the North.

HAMAMELIS MOLLIS Chinese Witch-Hazel

Deciduous shrub or tree capable of greater ultimate height than either *H. vernalis* or *H. virginiana*. Because of large, bright, spring-borne flowers it has more claim to intimate garden use, but is not dependable in all locations for a crop of regular annual bloom.

HAMAMELIS VERNALIS Ozark Witch-Hazel (Vernal Witch-Hazel)

A medium-sized, stocky, upright, deciduous shrub which is indifferent as to soil and able to withstand considerable shade. Though generally considered to be a spring-blooming plant, its fragrant, not too showy, yellow or red (variable with different plants) flowers may open during a warm period and carry on at each warm interval until spring. Its free-suckering proclivities may be thwarted by grafting on the roots of *H. virginiana*. A species for massing in woodland planting or along roadsides.

HAMAMELIS VIRGINIANA Common Witch-Hazel

Familiar, open, large, pleasant-leaved shrub of which isolated plants hide away in wood edges to there disclose themselves only after the leaves have fallen. From then on during warm periods until well into December, its fragrant flowers expand their strap-shaped petals to cheer up an otherwise desolate landscape. Therein lies the key to its garden value.

Hawthorn — See Crataegus

Heath — See Erica

Heather — See Calluna, Erica, and Daboecia

HEDERA HELIX var. BALTICA Hardy English Ivy

An outstandingly hardy, climbing form of a normally tender evergreen vine, like its type in aspect except for smaller foliage. Satisfactory as a high evergreen climber only when sheltered from winter sun and wind. The fruiting shoots, which have less interesting foliage, may be propagated to produce a bushy shrub. Such change to fruiting wood seldom comes before the limit of supporting structure is reached. Rapidly climbing plants rarely flower.

HEDERA HELIX var. CONGLOMERATA Bunchleaf English Ivy

A slow-growing, relatively hardy, small-leaved, shrub-like, evergreen form of the common Ivy, now popular in rock gardens.

Hedera helix var. minima

Another slow-growing form of the English Ivy for rock gardens. It has erect stems and small, pointed leaves which turn bronze in winter. It usually becomes spreading in habit through freezing back of growing tips.

HELIANTHEMUM NUMMULARIUM Common Sun-Rose

A subshrub usually met with in some one of its numerous garden forms. The type shows both upright and spreading habit, but, because of tenderness of top, it is usually but a few inches tall. When happy, it appears as a mat or tuft of pale-green foliage surmounted by numerous small, showy flowers. It can be used in sunny spots in rockeries, in walls, or in cracks of walks. Single and double color forms are offered by the trade.

Hemlock — See Tsuga

Hibiscus syriacus SHRUB ALTHAEA

Large, gray-wooded, upright shrub or small tree which has been much liked because of its late flowering (July to September). It is a vigorous grower as a young plant and hence not too hardy in inland locations. Older, slower-growing plants are more winter-resistant and usually prove hardy from Massachusetts south. It is rather stiff in habit to group well. Numerous varieties of value according to personal taste are available, such as **"Ardens"**, double lavender-violet; **"Banner"**, double white and crimson; **"Boule de Feu"**, double violet-red; **"Coelestis"**, single blue; **"Duc de Brabant"**, double red; **"Jeanne d'Arc"**, double white; **Lucy**, semi-double pink; **Rubis**, single red; and **"Totus Albus"**, single white.

Hippophae rhamnoides COMMON SEA-BUCKTHORN

A gray-foliaged, large, deciduous shrub or small tree with gray shoots and spiny branches. Its inconspicuous flowers are followed in September by numerous small, bright orange, persistent berries on the more spreading female plant. For such fruiting, presence of the more upright male plant is essential. It is indifferent as to soil, and because of free suckering has been used to bind sand dunes. Of little garden use except possibly as a hedge plant.

Holly — See Ilex

Hollygrape — See Mahonia

Honey-Locust — See Gleditsia

Honeysuckle — See Lonicera

Hornbeam — See Carpinus

Horse-Brier — See Smilax

Horsechestnut — See Aesculus

Huckleberry — See Gaylussacia

Hudsonia montana

A heath-like, evergreen subshrub from the mountains of North Carolina. Though rare in cultivation because it is difficult to transplant, it is quite possible in the rock garden. Here again is a plant which will serve as an example of the futility of collecting well-established plants from the wild.

HYDRANGEA ARBORESCENS var. GRANDIFLORA SNOWHILL HYDRANGEA

A relatively small, slightly coarse-textured, upright-branched, deciduous shrub which, in summer, terminates its shoots with rounded, white heads of sterile flowers. As with all Hydrangeas, growth and flower size are increased by cutting back in the spring. It will do remarkably well in poor, dry soil and will withstand some shade, although with loss of flower quality. If let go, it will spread rapidly and serve for a ground cover. However, for such purposes the wild type *H. arborescens* would seem to be more suitable.

HYDRANGEA MACROPHYLLA var. COERULEA

This is an interesting variety allied to, and probably hardier than, the colored, sterile-headed forms forced by the florists. While not of definite value inland, except in sheltered spots, plants of this species take to the outdoors in gardens near the sea. This particular form has large deep heads of perfect flowers ringed around by larger blue or white sterile blooms. If cut back in spring and given ample food and moisture, the plant will have a pleasing succulent aspect.

HYDRANGEA PANICULATA PANICLE HYDRANGEA

This is the type plant of the much overdone "Peegee" Hydrangea, but differs in that not all flowers are sterile and the resulting panicle is open and more interesting. Old flower parts persist as in "Peegee." While perfectly hardy and capable of being grown into a tree, such building up of woody framework will be at the expense of size, but not number, of flowers. Thus, if grown for individual flowers, it can well be pruned severely in spring. An excellent plant for growing in large masses. Var. **PRAECOX** has about the same garden value as the type but blooms six weeks earlier. Thought by some to be better than the type.

HYDRANGEA PETIOLARIS CLIMBING HYDRANGEA

A close-climbing, slow-growing, deciduous root climber for masonry walls or the trunks of otherwise worthless trees, capable of an ultimate spread of seventy-five feet or more. Mature plants are lighted up in July by a loose, whitish inflorescence with an outer ring of sterile flowers which persist in a dried state throughout the autumn. Plants on walls are interesting in winter when the rugged framework of brownish wood, close-hugged to the masonry, is opened to sight. This species differs from *Schizophragma hydrangeoides* in technical details only. Garden aspect is about the same except that the latter has poorer autumn effect. Both plants have been put forward by various authors as being superior, but of the two the Hydrangea seems to be more popular and to have greater garden distribution.

HYPERICUM AUREUM GOLDEN ST. JOHNSWORT

A relatively small, stiff, dense, deciduous shrub with pale-green foliage covered in July and August with bright-yellow flowers having prominent, showy, yellow stamens. Can withstand a certain amount of shade.

Hypericum Buckleyi MOUNTAIN ST. JOHNSWORT

A compact shrub to about one foot, having upright and spreading stems, bluish leaves, and small flowers. A plant for rock gardens or ground cover.

Hypericum calycinum

A somewhat tender-topped, evergreen species of little more than a foot high which, because of its persistent leaves and relatively large yellow flowers, can find a place in the rock garden. It has possibilities as a ground cover in warmer sections.

HYPERICUM KALMIANUM KALM HYPERICUM

A three-foot, narrow-leaved, hardy, deciduous shrub with smaller flowers than *H. aureum*. It can withstand shade and dry soil conditions, and on such situations could be used as ground cover. It has been suggested as material for a hedge which will require no clipping.

Hypericum prolificum SHRUBBY ST. JOHNSWORT

A deciduous shrub of variable habit but usually coarser than *H. Kalmianum*. Mentioned here for possible wild planting because of its ability to withstand both shade and soil moisture.

Larix leptolepis (*L. Kaempferi*) JAPANESE LARCH

This is one of the more handsome and quick-growing species of a group which, because of botanical association and aspect are often classed facetiously as "deciduous evergreens." It will grow into a tall tree of fine texture which in winter displays a reddish cast to its young branches. All larches are subject to attack by serious insect enemies and disease.

Laurel — See Kalmia

LAVANDULA SPICA SPIKE LAVENDER

Though capable in milder climates of getting up to some three feet in height, this familar, gray-leaved, lavender-flowered plant seems to benefit from severe cutting back in spring. So treated, it has a place in the rock garden.

Leatherleaf — See Chamaedaphne

Leatherwood — See Dirca

LEDUM GROENLANDICUM LABRADOR-TEA

An upright, evergreen shrub of northern bogs and mountain slopes. Its inch-long, evergreen leaves have brown-felted undersurfaces, and its whitish flowers appear in May or June. Var. **COMPACTUM** has been described but probably is not available in this country.

LEIOPHYLLUM BUXIFOLIUM BOX SANDMYRTLE

A low, evergreen shrub which appears in various phases throughout the eastern seaboard. Of the taller forms, one of the best is that found wild in the sand barrens of New Jersey. This northern form makes a neat bush up to some eighteen inches in height with interesting, small, shining, evergreen foliage and white flowers in May or June. In garden value it is comparable to var. **HUGERI**. This and the slower-growing, more prostrate var. **PROSTRATUM** from the Carolina mountains are both fine rock-garden plants. If handled as large plants, any of these forms had best be cut to the ground at time of transplanting.

LESPEDEZA THUNBERGII (*L. formosa*) (*Desmodium penduliflorum*) PURPLE BUSHCLOVER

A "die-back," root-hardy, multiple-branched shrub which forms a five- or six-foot, herbaceous-appearing mass of pendulous stems terminating in late summer in panicles of rosy-purple flowers. Much used in the bays of large shrub plantings or sometimes for informal hedges.

LEUCOTHOE CATESBAEI DROOPING LEUCOTHOE

A tall, slow-growing, evergreen shrub with shining leaves ranged along arching branches which terminate in racemes of white, bell-shaped flowers in late spring. When used in general ericaceous plantings in the North, it is prone to burn badly in early spring or to become ragged as it grows older. Hence, in cultivation it had best be planned for as a relatively small shrub kept down by annual removal of old or winter-injured branches at ground level. So treated, it becomes well worth while.

Leucothoe racemosa SWEET BELLS

A native, deciduous shrub having pleasant foliage, racemes of white flowers in late spring, and brilliant autumn foliage color. Useful for roadside or wild plantings. Not as valuable in gardens as Enkianthus or *Vaccinium corymbosum*.

LIGUSTRUM AMURENSE AMUR PRIVET

This privet makes up in hardiness what lack of foliage luster it may have in comparison to the semi-evergreen *L. ovalifolium*. This extra hardiness is apparent in the manner in which the plant hardens its wood, drops its leaves, and settles down for the winter. For tall clipped or natural hedges.

X LIGUSTRUM IBOLIUM

A supposed hybrid between the tender *L. ovalifolium* and the rugged *L. obtusifolium*, resulting in a hardier hedge plant which retains most of the glossy, broad-leaved character of the ordinary "California Privet." Not at all evergreen, it seems to have justly displaced the less hardy *L. ovalifolium* in New England gardening.

LIGUSTRUM OBTUSIFOLIUM var. **REGELIANUM** REGEL PRIVET

A truly deciduous Privet which is to be looked upon not as a hedge plant but as a low shrub with almost level, spreading branches covered in winter with masses of attractive black fruits which follow the nodding panicles of white flowers of late spring. Valuable for general mixed plantings. It can, with sacrifice of fruit, be used for clipped hedges or, by severe annual cutting, for bank covering.

Lilac — See Syringa

Linden — See Tilia

Lindera aestivale (*Benzoin aestivale*) SPICEBUSH

Tall, gaunt, long-lived, deciduous shrub for natural planting in moist, half-shaded soil at edges of woods. It has bright yellow flowers in early spring before the leaves; and in autumn, yellow foliage coloration accompanied by small crimson berries which are much enjoyed by birds.

Linnaea borealis var. americana AMERICAN TWINFLOWER

A creeping, prostrate, evergreen shrub which has small, rounded leaves; small, fragrant, white or pink flowers; and tiny yellow fruits. Difficult to cultivate except in shady, moist, peaty soil in woodland or rock garden.

LIQUIDAMBAR STYRACIFLUA SWEET GUM

In the North this tall inhabitant of southern swamps settles down on reasonably deep, moist soil to be a fifty-foot, pyramidal tree of considerable distinction. Its star-shaped leaves, brilliant autumn color, gray bark, corky-ridged branches, and decorative brown fruits tend to give it seasonal interest. It has proved difficult to transplant in larger sizes.

Liriodendron Tulipifera TULIP TREE

A familiar, tall, clean-boled, woodland tree with broad-lobed leaves and tulip-like flowers. The var. **PYRAMIDALE** is particularly valuable to gardening because of its upright branching habit which builds up a tall, narrow outline. A superior substitute for the discredited Lombardy Poplar, but difficult to transplant in large sizes.

LITHOSPERMUM DIFFUSUM

The tender, gray-leaved, lime-loving prostrate shrub with blue flowers which, though desirable when happy, has been found difficult of culture in many eastern rock gardens.

Locust — See Robinia

LOISELEURIA PROCUMBENS ALPINE-AZALEA

A tiny, multiple-branched, tufted, evergreen shrub which inhabits high mountain regions in New England. When suited, it forms mats covered with quarter-inch leaves and in June or July bears white or rose-colored flowers. For the rockery.

LONICERA FRAGRANTISSIMA Winter Honeysuckle
A large, slightly top-tender, rounded shrub which tends, in warmer sections, to retain its broad, dark-green leaves well into the winter. It bears early, fragrant, white flowers which are followed by red berries. Like all Honeysuckles, it can withstand a considerable degree of shade.

LONICERA HECKROTTII Everblooming Honeysuckle
A short, non-rampant, slightly twining, deciduous vine with smooth, stemless, gray leaves. Its two-toned flowers of reddish-purple outside and yellowish purple within are borne profusely from June to September. For garden use it is related to other climbing Honeysuckles about as *Clematis texensis* is to the more vigorous species of its genus. It may be of hybrid origin. It must be protected against aphids.

Lonicera Henryi Henry Honeysuckle
A vine sometimes favored because of the almost completely evergreen property of its elongated leaves. Good for ground cover. Not too top-hardy.

LONICERA JAPONICA var. HALLIANA Hall Japan Honeysuckle
A well-known, nearly evergreen, twining vine for ground cover, fences and screens. In summer it bears pure-white, fragrant flowers which change later to yellow. Much of the material in the trade and in naturalized plantings under this name are type plants of seedling origin which have fewer flowers of white, tinted purple. This variety, in name at least, is as fixed in the popular mind as Honeysuckle as is *Clematis paniculata* for its genus. A rank grower which, unfortunately, is capable in warmer areas of driving out many native plants.

LONICERA KOROLKOWII var. FLORIBUNDA
Broad Blueleaf Honeysuckle
A truly large but not coarse, deciduous shrub with rounded, bluish leaves and in early summer numerous small pink flowers. It needs plenty of room (twenty or more feet) in which to develop fully its pleasing spreading outline. It can, of course, be kept smaller by understanding pruning.

LONICERA MAACKII var. PODOCARPA Late Honeysuckle
A very tall (fifteen feet or more), spreading, deciduous shrub having dark, rounded, long-persistent leaves and fragrant white flowers which fade yellow and are followed by dark red fruits. A plant for the large border or wherever else it may be given sufficient room.

LONICERA MORROWII Morrow Honeysuckle
A thoroughly hardy, heavy-wooded, deciduous shrub with rounded leaves, white flowers in May changing to yellow and dark red, and late-summer fruits. Because its habit is to grow some six feet high and fifteen to twenty feet across, it is usually out of place in any but very extensive plantings. Var. **XANTHOCARPA** has yellow fruits.

LONICERA PILEATA Privet Honeysuckle
A top-tender, flopping-branched, nearly evergreen, Bush Honeysuckle which, where hardy, can spread out in ground-covering mats on banks, walls, or in the large rockery. Its white flowers of April or May are followed by purple fruits.

LONICERA SEMPERVIRENS var. SULPHUREA YELLOW TRUMPET HONEYSUCKLE
A yellow-flowered Honeysuckle, otherwise like var. *superba*. Much of the supposed *L. flava* of the trade is probably of this variety.

LONICERA SEMPERVIRENS var. SUPERBA
A vigorous, climbing, smooth-leaved, deciduous variety of the Trumpet Honeysuckle. In summer it bears deep scarlet, scentless flowers clustered at the ends of the branchlets. Useful for flowering effect on trellisses, fences, or when grown wild over worthless shrubs and trees. It is as attractive to aphids as a Nasturtium.

LONICERA SPINOSA var. ALBERTI
A deciduous Bush Honeysuckle which has slender, flopping branches, narrow, bluish leaves, fragrant pink flowers, and bloomy fruits. It can be used to advantage on banks or in the very large rockery.

LONICERA TATARICA var. ROSEA PINK TATARIAN HONEYSUCKLE
A hardy, ten-foot, upright, deciduous shrub with large dark foliage and numerous fragrant pink flowers in May. The red berries of late summer are, unless eaten by birds, somewhat persistent. A plant for the wide border or large informal hedge.

LONICERA THIBETICA TIBETAN HONEYSUCKLE
A hardy, deciduous shrub with confused prostrate branches which, if left unpruned, tangle together and pile up eventually into a four- or five-foot, shiny-leaved mass with purplish-pink flowers in late May. Best suited for group plantings on banks, retaining walls, or rough slopes. It is suggested here in place of *L. syringantha* var. *Wolfii* which is too rampant for most limited garden areas.

Lycium chinense CHINESE MATRIMONY-VINE
A rugged, pendulous-branched, deciduous shrub, or, if a support is available, a clambering climber. Small purple flowers, red fruits, and long-persistent leaves make it a suitable covering for low, rough structures or rocky areas where nothing in the way of maintainance is available. Spreads rapidly by volunteer seedlings and has little place in fine gardening.

Lyonia mariana (*Pieris m.*) (*Xolisma m.*) STAGGER-BUSH
A coarse, deciduous, native shrub growing to some six feet in height on low areas. Because of its adaptability to moist places and its sprays of nodding whitish flowers, this plant can find a limited place in broad, wilder planting.

Magnolia acuminata CUCUMBER TREE
A very large, eastern-American tree which, like many another plant, grows up through an interestingly pyramidal juvenile stage to spread out a broad top at maturity. Has six- to ten-inch, pale-green leaves, insignificant flowers, and cucumber-like fruits which show bright red seeds in late summer. Var. **CORDATA** has broader leaves, and canary-yellow flowers.

MAGNOLIA DENUDATA (*M. conspicua*) YULAN
A gray-barked, open-topped tree up to thirty feet or more, which bears six-inch, fragrant, white flowers in early spring before the unfolding of the leaves. Its expanding flower parts are sometimes injured by frost.

MAGNOLIA SIEBOLDII (*M. parviflora*) OYAMA MAGNOLIA
A small, somewhat tender, deciduous tree or large shrub up to some thirty

IBERIS SEMPERVIRENS EVERGREEN CANDYTUFT

A familiar, white flowered, evergreen edging or rock-garden plant. "**LITTLE GEM**" is a neat, dwarf form for rockeries.

ILEX CRENATA VAR. CONVEXA

A cup-leaved and apparently somewhat hardier form of a variable evergreen species which needs protection over almost all of inland New England. Where guarded against winter sun and wind, and not subjected to extremely low temperature, it will usually get through the winter with but the loss of some of its soft, late-summer shoots. It is capable of becoming a bush some twenty feet in height, with shining, persistent foliage and a winter crop of quarter-inch black berries on pistillate plants. It will react to winter nipping or to shearing by becoming quite dense in aspect.

ILEX GLABRA INKBERRY

A loose-branched, native, evergreen shrub which, under the protection of cultivation, settles down to be a particularly satisfactory plant with upright stems, interesting shining foliage, and black fruits. Like most evergreen shrubs, its foliage will at times burn in winter if subjected to sun and wind, especially if the soil becomes deficient in moisture. Its fruits are attractive to birds.

ILEX OPACA AMERICAN HOLLY

A familiar coastal-plain plant which does not do well inland. Where hardy, it responds well to feeding and other practices of high culture. Strains are now being selected for hardiness, foliage quality, and fruiting properties.

Ilex rugosa

A low, spreading or prostrate, evergreen shrub which has smooth branches, lustrous wrinkled leaves, and small red fruits. For the larger rock garden.

ILEX VERTICILLATA COMMON WINTERBERRY

This is the tall, gaunt, Black Alder of swamps which is familiar to all New Englanders because of its large, paired, red berries which are much used in early winter decoration and interesting to birds. It will grow happily on higher ground, but plants of both sexes must be present if fruiting is to be expected.

INDIGOFERA KIRILOWII KIRILOW INDIGO

Somewhat of a "die-back" shrub which has the ability to come from the ground each spring to carry its rose-colored racemes of pea-shaped flowers against some three feet of soft, locust-like foliage in June or early July. It is a somewhat spreading plant suitable for covering large banks.

Inkberry — See *Ilex glabra*

Ivy — See Hedera and Parthenocissus

Japanese Quince — See Chaenomeles

Jersey Tea — See Ceanothus

Jetbead — See Rhodotypus

Judas Tree — See Cercis

Juglans nigra BLACK WALNUT

A large, handsome, nut-bearing, timber-producing tree of the deeper soils of sections farther west, which is finding its way into New England in cultivated strains. It is best transplanted when very young or grafted on established seedlings.

Juniperus chinensis var. columnaris

Probably the best of the upright forms of a quite variable species, and with some pruning will develop into a tall, narrow, gray-green column some fifteen to twenty feet in height. In some situations it will replace the native Red Cedar which in smaller sizes is notoriously difficult to transplant. This, like a great many other Junipers, must be carefully protected against attack of the red spider mite. A brilliant green form is sometimes offered.

JUNIPERUS CHINENSIS var. JAPONICA Japanese Juniper

Of a decided vase-shaped appearance when young, this hardy variety spreads out horizontally and seldom reaches a height of more than three or four feet. For the very large rockery or for planting at the bases of buildings.

JUNIPERUS CHINENSIS var. PFITZERIANA Pfitzer Juniper

Perhaps the most amenable of all Junipers to the rigors of cultivation — transplants easily, fills up nicely without change of habit if given corrective pruning, and seems to withstand city conditions as well as an evergreen can. While it is sometimes unnaturally trained to a central leader, its normal habit is that of a spreading (wider than high) bush reaching out graceful, horizontal branches which are covered with gray-green foliage. It will, in time, spread to be some ten to twelve feet across if not restrained by pruning out of leading shoots.

JUNIPERUS CHINENSIS var. SARGENTII Sargent Juniper

A low, evergreen shrub which sends up ascending branchlets from its procumbent stems. If planted in masses and let go, it will in time cover rough sunny areas with a pleasant mass of gray or bluish green, but does not do well in the shade.

Juniperus communis var. depressa Prostrate Juniper

This is the prostrate form of the pasture Juniper so well known in New England. Since it is such a definite part of our native landscape, its further use in roadside and broad natural development seems indicated. The fruits of this species are eaten by some native birds. Like all forms of *J. communis*, it must be carefully watched for infestation of the Juniper webworm. Also forms of *J. communis* may serve as alternate hosts to fungi which cause rust diseases on many rosaceous plants.

Juniperus communis var. suecica Swedish Juniper

A tall, slender plant somewhat like the much-planted Irish Juniper but having branchlets with drooping tips. Preferred to var. **hibernica** by some tradesmen because of somewhat better early spring appearance. This and other upright varieties of *J. communis* are hard to group and are losing the garden popularity which they formerly had.

JUNIPERUS CONFERTA (*J. litoralis*) Shore Juniper

A creeping, procumbent shrub with upright branchlets covered with spiny, pointed, bluish-green leaves. Suitable for use as a neat-appearing ground cover on open, sandy areas in the warmer sections near the sea. It has interesting, large, bloomy, black fruits.

JUNIPERUS HORIZONTALIS var. DOUGLASII Waukegan Juniper

A trailing, fast-spreading variety with steel-blue leaves which become purplish in winter. It will do well in dry, sandy situations and makes an excellent ground-cover plant for open, sunny spots. It seldom reaches up to a height of more than one foot at any point.

JUNIPERUS HORIZONTALIS var. GLAUCA BAR HARBOR JUNIPER

This varietal designation seems in New England to apply to the fine, bluish, densely matting form that is found near the sea in the vicinity of Bar Harbor, Maine. When used in cultivation as a ground-cover plant, it forms an earth-hugging, tufted carpet. In winter, the foliage assumes a purplish or lavender color. Justly rated as one of the best ground-cover plants among the Junipers.

JUNIPERUS HORIZONTALIS var. PLUMOSA ANDORRA JUNIPER

A low, spreading shrub which seldom sends its fine-foliaged, upright branches to a height of more than fifteen or eighteen inches. In spreading, it maintains an almost regular circular outline. Hence, a single plant standing alone lacks an appearance of pleasing informality. When planted in masses so that the branches may interlace and the identity of the individual plants be lost, the result is an interesting, grayish-green ground cover which in winter turns lavender and lilac. This, like most other prostrate Junipers, is handled best while the plants are quite young.

Juniperus procumbens

A rather coarse, spiny-leaved, prostrate, evergreen shrub which on level ground will sometimes pile up to a height of two to three feet. Its greatest value as a garden plant is brought out when it is planted at intervals at the top of a retaining wall in such a way that it can throw forward and spill down toward the ground with its main stem at an angle to the stonework and the tips of its branchlets turning outward and upward. So used, the open, ragged appearance which comes with age cannot destroy its pleasing effect.

Juniperus Sabina SAVIN JUNIPER

A spreading, many-branched, evergreen shrub of soft texture, which was used frequently in the past as low material for the edges of groups about the bases of buildings. It does well in light, sandy soils. Var. **TAMARISCIFOLIA** is of more horizontal habit and has coarser, more interesting foliage, but does not always winter well. Like the type it usually becomes ragged with age.

JUNIPERUS VIRGINIANA var. CANAERTII CANNART RED CEDAR

A narrow, dark green, columnar, garden form of the variable Red Cedar. The dark, dense, foliage background, which persists satisfactorily without shearing, in autumn shows off the bloomy blue fruits to distinct ornamental advantage. Like all forms of *J. virginiana*, it is difficult to transplant, particularly in smaller sizes. Also, like most of the other forms of the genus, its berries are attractive to some native birds.

JUNIPERUS VIRGINIANA var. GLAUCA SILVER RED CEDAR

A somewhat narrow, upright, garden form of the Red Cedar, having pleasant blue foliage. Since it is usually propagated by grafting from side branches of the mother plant, this, like other similarly produced conifers, must be trained to a single leader while young if it is to grow up to be of true columnar habit.

JUNIPERUS VIRGINIANA var. KETELEERI

A rather tall, broad-based, conical plant of dense aspect which has its outline broken by the tips of the somewhat fleshy twigs. In autumn, it bears large, showy, slate-blue berries of considerable decorative value. This variety, unlike other forms of *J. virginiana*, seldom serves as a host to the cedar apple rust.

Juniperus virginiana var. Schottii SCHOTT RED CEDAR

A form which grows into a rather small, formal, compact, bright green column. It retains its color well throughout the winter and is reported to be amenable to shearing when used as a hedge plant.

Kalmia angustifolia LAMBKILL

A straggling, small-leaved, reddish-flowered plant of hillsides and meadows which can be massed on banks or in open, grassy areas along roadsides. There are numerous forms based on color of June or July flowers or stature, such as var. PUMILA which is dwarf enough for rock-garden use.

KALMIA LATIFOLIA MOUNTAIN LAUREL

This broad-leaved, evergreen shrub with its varying white to pink flowers is deservedly rated as one of the most beautiful, most popular, and most useful of the native woody plants. A number of varieties based on flower color or character have been described but are not generally available. The var. MYRTIFOLIA, which may be had in limited quantities, is valuable because of its smaller, darker leaves and slower habit of growth.

Kalmia polifolia BOG KALMIA

A straggling, evergreen shrub which in cold northern bogs and mountains gets up to two feet in height. Its small, persistent, slightly curled leaves are white beneath. It bears rose-purple flowers in early summer. A plant which finds limited use in wild gardening or, sometimes, in rock gardens.

Kentucky Coffee-Tree — See Gymnocladus

Kerria japonica KERRIA

A broad, loose, thin-wooded, green-stemmed, deciduous shrub which bears a profuse crop of single yellow flowers in May or early June and occasionally thereafter until frost. Winterkilling of tips prevents its becoming a tall plant. The winter effect of its green stems makes it useful for mass planting. Var. PLENIFLORA, with double flowers, is more popular at the moment because of greater vigor and more distinctly shrub-like aspect.

KOELREUTERIA PANICULATA GOLDENRAIN TREE

Usually seen in New England as a small, gawky, deciduous tree, or a very large shrub. With its large compound leaves, summer-borne panicles of yellow flowers, and papery fruits, it can be used at the back of the large border or sometimes as an isolated plant. Like the Flowering Dogwood or the Hawthorns, it becomes easy prey for wood-boring insects if moved in large sizes.

KOLKWITZIA AMABILIS BEAUTY-BUSH

A large, graceful, deciduous shrub, which, since its rather recent introduction, has rightly begun to displace some of the less hardy and less desirable Diervillas or Deutzias. Its pendulous branches are covered in June with clusters of pink flowers. In habit it is far less stiff and gardenesque than the Weigelas.

LABURNUM ALPINUM SCOTCH LABURNUM

This small, deciduous tree or large, stiff, upright shrub has been shown by cultural experience to be the most satisfactory species for New England. It has definite garden value when covered in late June with Wisteria-like racemes of deep yellow, pea-shaped flowers. Laburnums do not respond kindly to training by severe purning.

Larch, Golden — See Pseudolarix

feet or more, which bears rounded, six-inch, cupped, fragrant, white flowers in very late spring and occasionally thereafter.

X MAGNOLIA SOULANGEANA Saucer Magnolia

This hybrid of garden origin typifies the Magnolia in the popular mind. It is a small, gray-barked, deciduous tree or large shrub which is seen usually in the form of one or the other of several locally confused varieties. Var. **LENNEI** has flowers which are rosy-purple outside and white within; var. **RUSTICA** is more rose-red in flower color; var. **ALBA** has flowers more nearly white. In all varieties the six-inch flowers open in late April or May before the leaves unfold.

MAGNOLIA STELLATA Star Magnolia

A small, bush-headed, fine-textured, deciduous tree or large shrub to some fifteen feet. Its star-shaped, fragrant, white flowers brave the cold and storms of spring before the appearance of the relatively small leaves. The flowers of var. **ROSEA** are suffused with pink on the outside surfaces of the petals.

Magnolia virginiana (*M. Glauca*) Sweet Bay

An eastern coastal plain plant from Cape Ann — hence the name for the town of Magnolia, Massachusetts — to Florida and Texas. In the North it becomes a small deciduous tree or large shrub. Its small, fragrant, cup-shaped, white flowers, which appear with or after the leaves, give way to small fruiting cones which release bright red fruits.

Mahonia Aquifolium Oregon Hollygrape

A slow-growing shrub with evergreen, or, in inland locations, long-persistent Holly-like leaves which in autumn turn shining purple. Its prominent, yellow flower clusters of early May are followed by black, bloomy fruits. Though hardy over a large part of New England, this plant will not be a true evergreen shrub unless given ample winter moisture and protection from direct winter wind and sun.

Mahonia repens Creeping Hollygrape

Spreading by underground stems, this foot-high ground cover has somewhat Holly-shaped, dull bluish-green, slightly persistent leaves which do not turn a high autumn color.

Maidenhair Tree — See Ginkgo

MALUS Flowering Crabapples

Here is a bewilderingly complex group of species and natural or garden hybrids in which there are some highly ornamental and useful plants for New England. Possessed of fitting habit, coming into flower in early May, and lighting up the autumn with showy fruits, they seem more adaptable and more amenable to garden treatment than do the Hawthorns with which they compete. Like the Thorns, apple fruits of any sort furnish valuable game food.

Of the numerous clons in cultivation, it has been determined that those of native origin are more susceptible to the cedar apple rust than are those from the Orient. A few of the better and more familiar forms are listed here.

X MALUS ARNOLDIANA Arnold Crab

A single, pink-flowered, hybrid Crabapple with larger leaves, paler flowers, and larger, all-yellow fruits than the parent, *M. floribunda*. Of Asiatic origin.

X MALUS ATROSANGUINEA Carmine Crab

A hybrid Crab which builds up a fine-twigged, bush-like plant with shining, toothed leaves; single, slightly garish, rose-purple, non-fading flowers; and small, dark red fruits. Both parents are Oriental species.

MALUS FLORIBUNDA JAPANESE FLOWERING CRAB

A free-flowering, Asiatic species which becomes a twenty-five foot tree bearing single, pink flowers which fade out to white and are followed by small, red and yellow fruits.

MALUS HUPEHENSIS (*M. theifera*) TEA CRAB

A Chinese species which grows into a twenty-five foot tree of rather stiff, cherry-like appearance. Its freely borne, single, pink flowers fade out white and are followed by small, greenish-yellow fruits with red cheeks.

Malus ioensis var. plena BECHTEL CRAB

A pleasing, double, pink-flowered variety of a native species which forms a rather heavy-branched, round-headed tree to some thirty feet in height. Its well-deserved popularity of the past has been much dimmed by the fact that its foliage and soft growth is severely attacked by the cedar apple rust.

Malus pumila var. Niedzwetzkyana REDVEIN CRAB

This form of the Eurasian parent species of many pomological varieties is of interest because of the red color which carries through its stems, leaves, flowers, and fruits. It is of greatest ornamental value as an older plant.

X MALUS PURPUREA var. ELEYI ELEY CRAB

One of a group of hybrids which carries over in its red-stained wood, lustrous purplish leaves, and purple fruits, the parental traits of *M. pumila* var. *Niedzwetzkyana*. The flowers of this form are reddish-purple, well formed, and freely borne.

MALUS SARGENTI SARGENT CRAB

A six-foot, somewhat spiny shrub with shining leaves, inch-wide white flowers, and half-inch, deep-red, showy fruits. Though a wild species from Japan, its proved interfertility with other Crabs indicates the necessity for vegetative propagation if the dwarf habit is to be preserved.

X Malus Scheideckeri SCHEIDECKER CRAB

A hybrid of two Asiatic species which forms a small, upright tree of some fifteen feet, bearing semi-double, pale-pink flowers and three-quarter-inch yellow fruits.

Malus spectabilis CHINESE FLOWERING CRAB

A twenty-five-foot Asiatic species with exceptionally showy, semi-double, pink flowers and relatively large, lusterless, yellow fruits.

MALUS TORINGOIDES CUTLEAF CRAB

An Asiatic shrub or small, open tree to twenty-five feet, bearing Hawthorn-like leaves; single, white, unspectacular flowers; and showy, slightly pear-like, red-cheeked yellow fruits in drooping clusters.

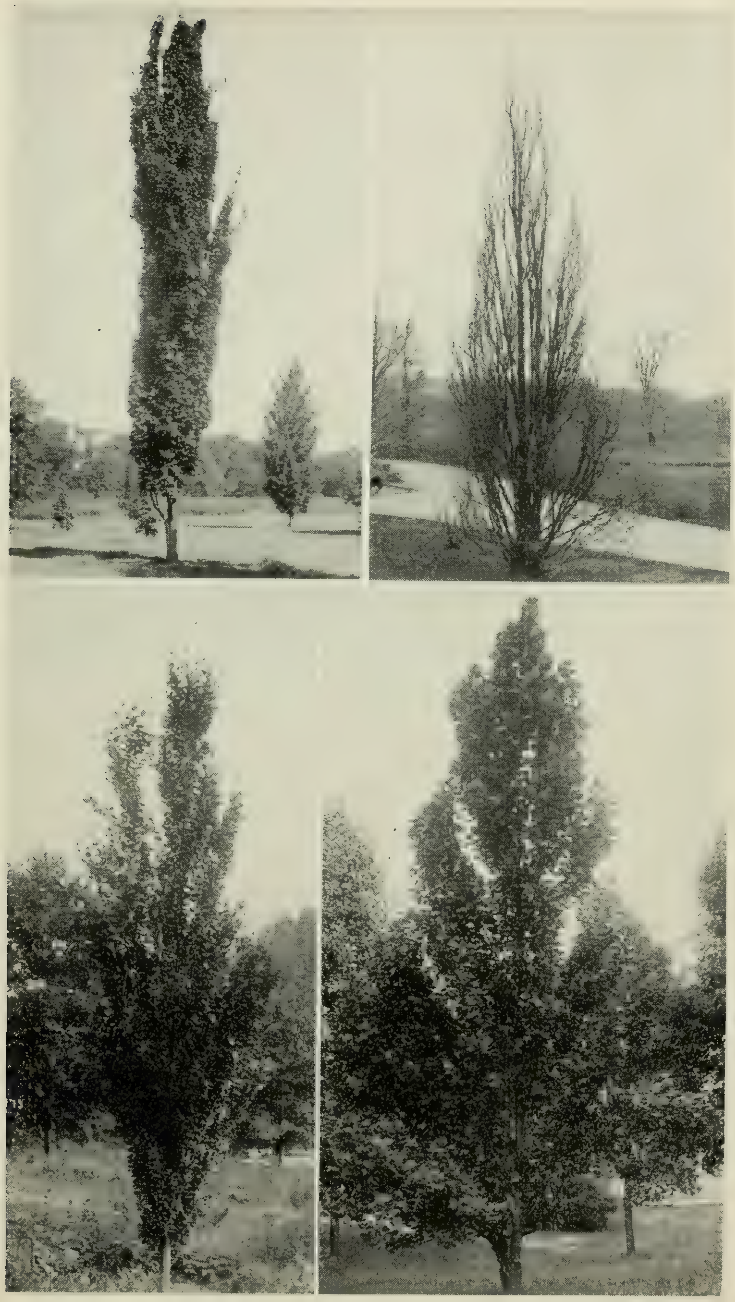
Maple — See Acer

Matrimony-Vine — See Lycium

MITCHELLA REPENS PARTRIDGE-BERRY

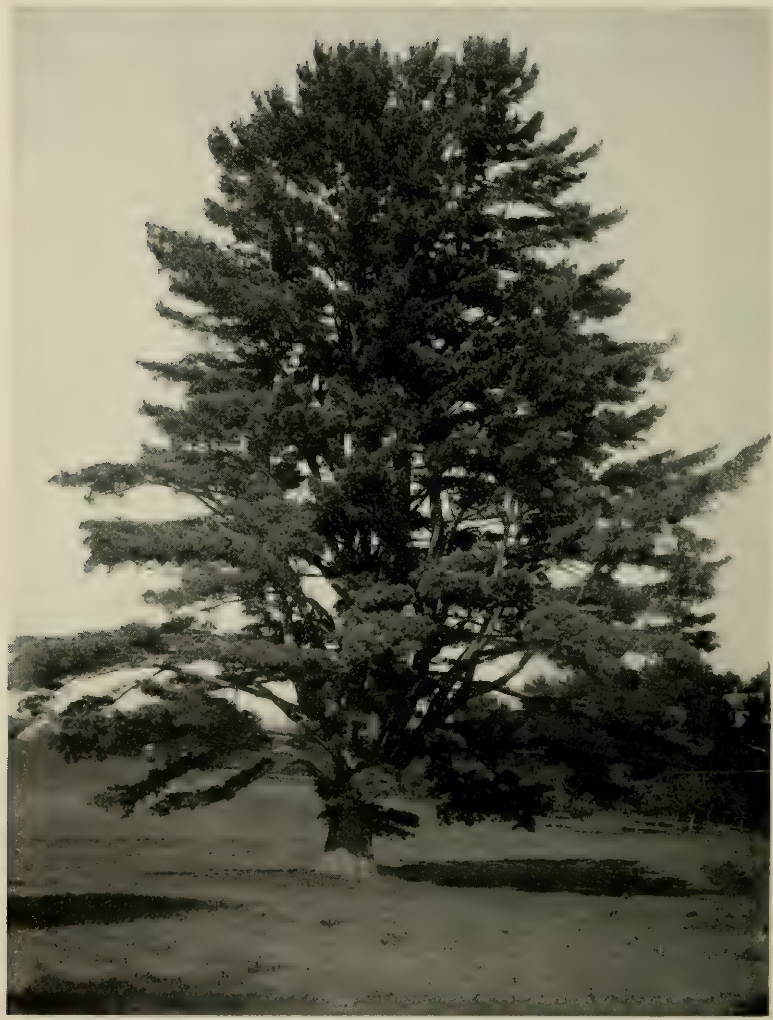
A prostrate, creeping plant with three-quarter-inch evergreen leaves and persistent red berries. A neat ground cover beneath large evergreen trees, or for dry, partially shaded situations in the large rockery.

Mock-Orange — See Philadelphus

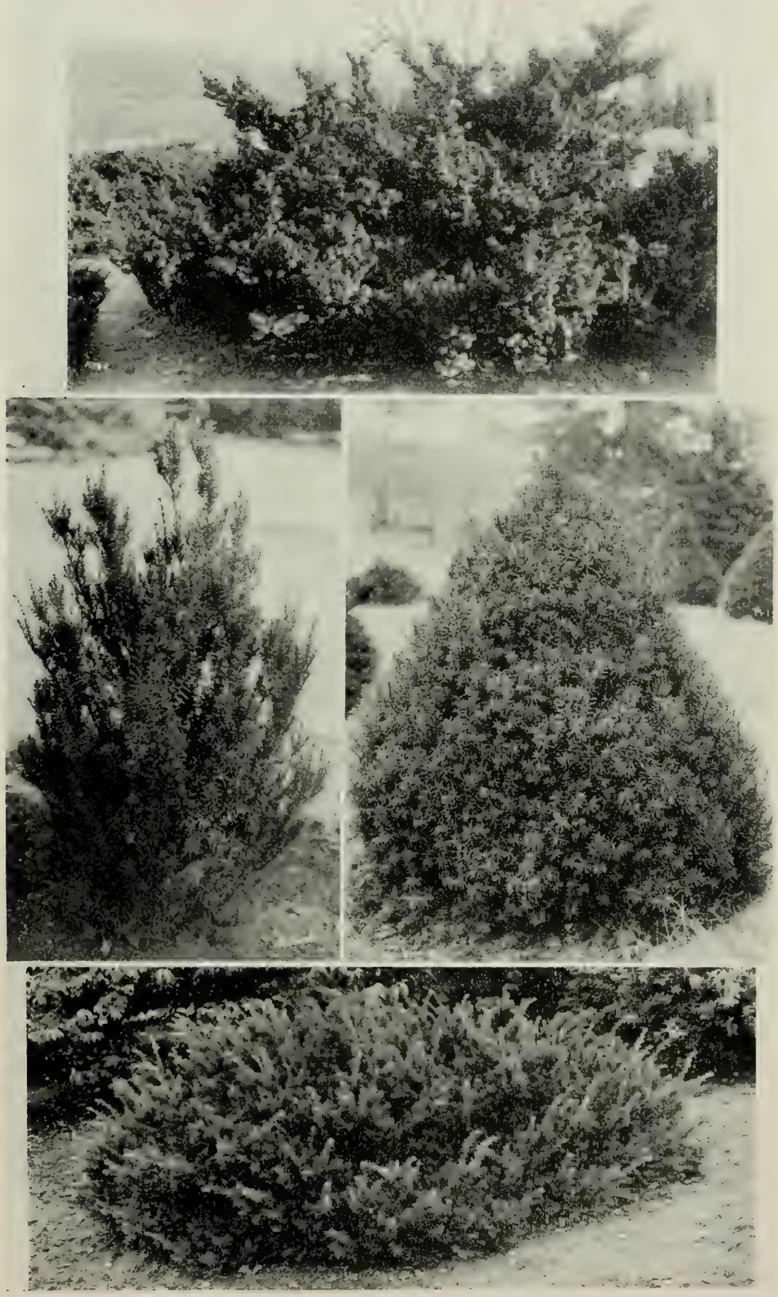


Trees of Fastigiate Habit

Upper Left (foreground): Acer saccharum var. monumentale (Columnar Sugar Maple).
(background): Acer rubrum var. columnare (Columnar Red Maple).
Upper Right: Quercus robur var. fastigiata (Fastigiate English Oak).
Lower Left: Fagus sylvatica var. fastigiata (Fastigiate European Beech).
Lower Right: Liriodendron Tulipifera var. pyramidale (Tulip Tree).



Pinus Strobus (White Pine) in Age



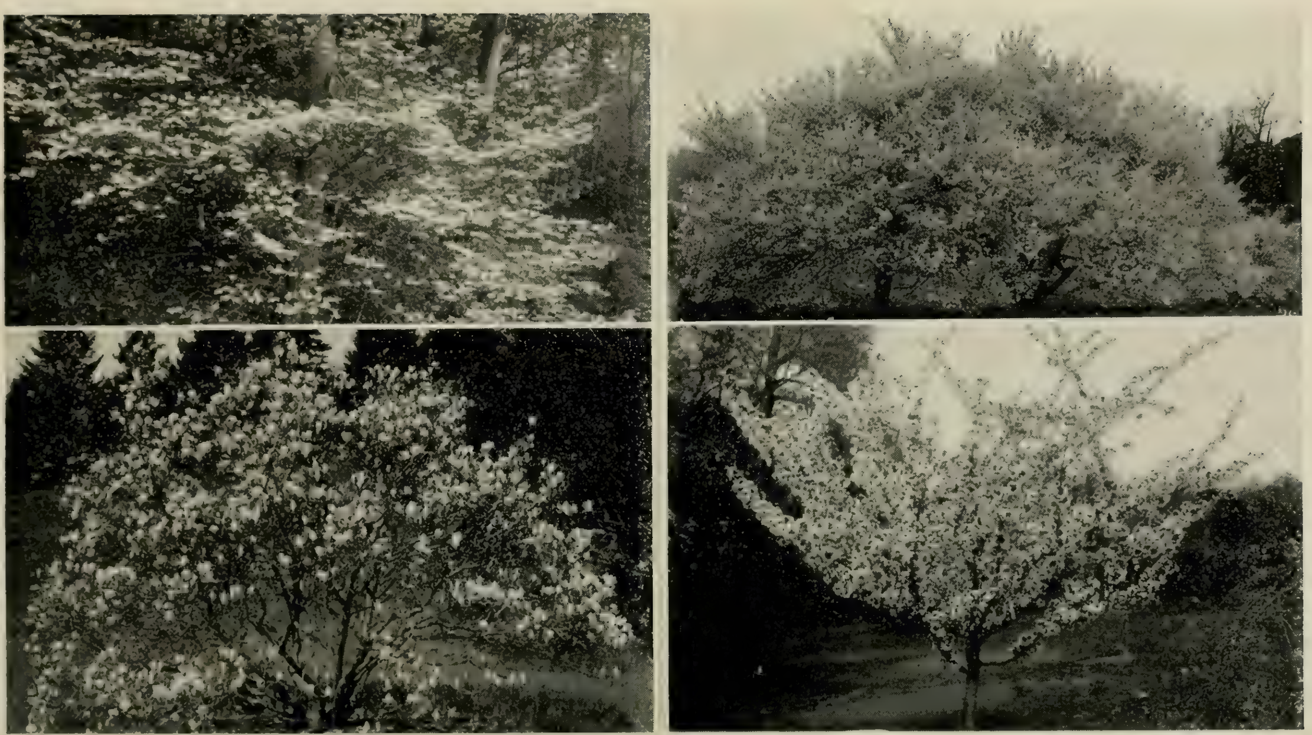
Yews

Top: Taxus cuspidata var. nana.

Left Center: Taxus media var. Hicksii.

Right Center: Taxus media var. Hatfieldii.

Bottom: Taxus cuspidata var. Thayerae.



Flowering Trees

Upper: Cornus florida (Flowering Dogwood).
Lower: Magnolia Soulangeana (Saucer Magnolia).

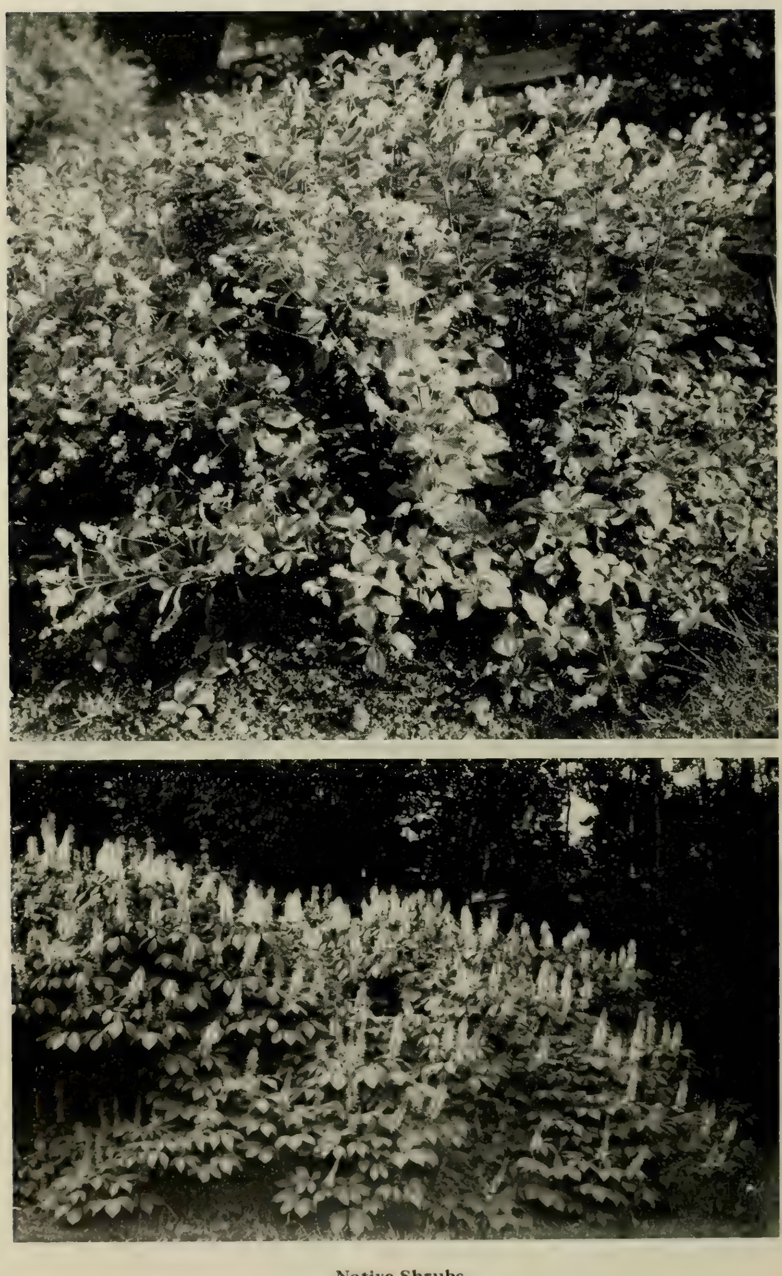
Upper: Prunus subhirtella (Higan Cherry).
Lower: Malus hupehensis (Tea Crab).

Vines

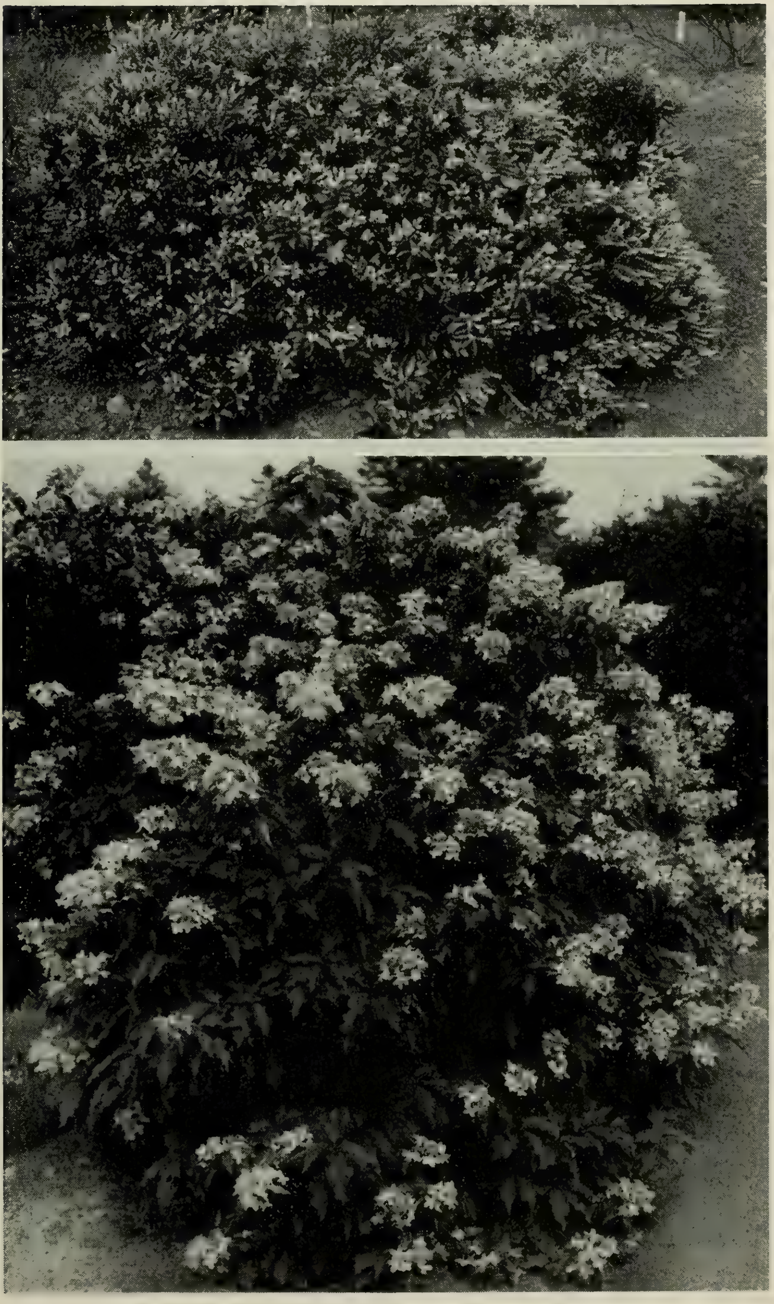
Wisteria floribunda (Japanese Wisteria).

Vitis labrusca (Fox Grape).

Hydrangea petiolaris (Climbing Hydrangea).



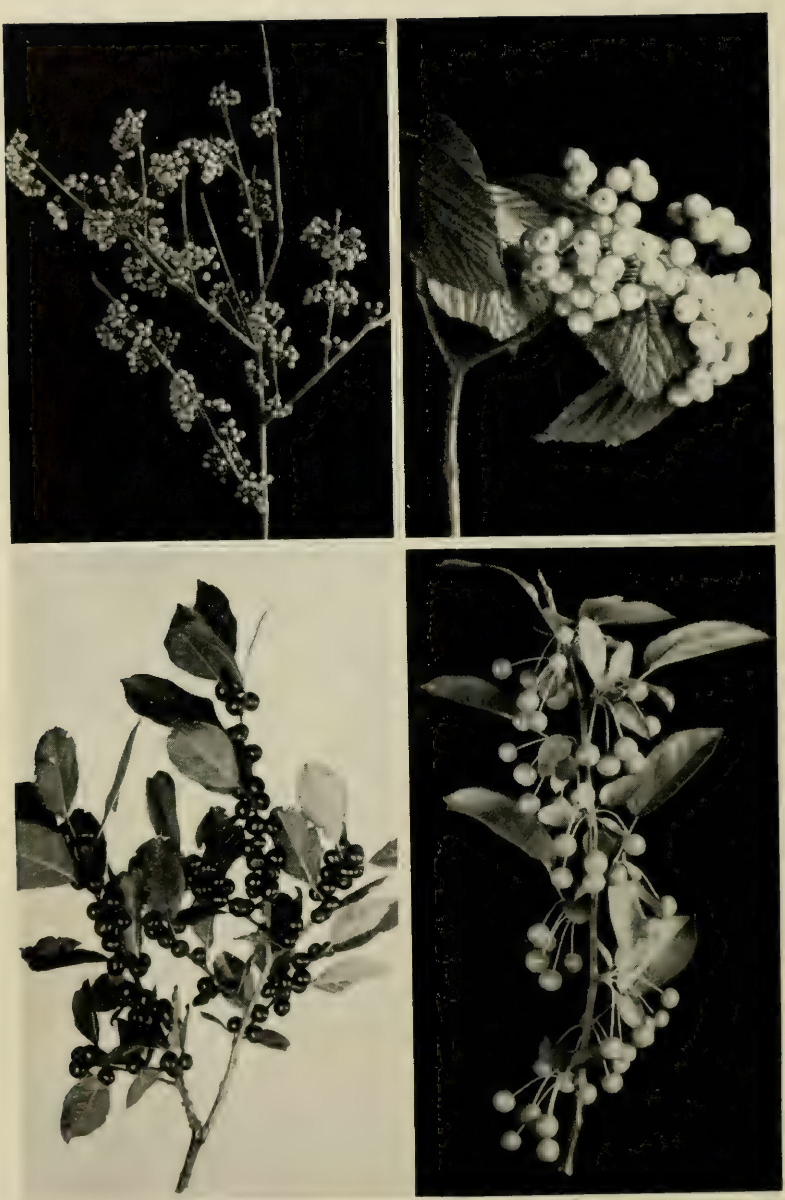
Native Shrubs
Upper: Ceanothus americanus (New Jersey Tea).
Lower: Aesculus parviflora (Bottlebrush Buckeye).



Flowering Shrubs

Upper: Pieris floribunda (Mountain Andromeda).

Lower: Hydrangea paniculata var. praecox (Panicle Hydrangea).



Berried Shrubs

Upper: Callicarpa japonica (Japanese Beautyberry).
Lower: Ilex verticillata (Common Winterberry).
Upper: Viburnum Wrightii.
Lower: Malus Sargenti (Sargent Crab).

Morus rubra RED MULBERRY

A medium-sized native tree which is sometimes planted in bird sanctuaries because of its attractive, juicy, dark-purple fruits in midsummer.

Mountain Ash — See Sorbus

Mountain-Holly — See Nemopanthus

Muehlenbeckia axillaris

A small, straggling, prostrate, deciduous shrub having thin stems which form a mat some twelve inches across, in hot, dry, well-drained, rock-garden situations. The form cultivated as **M. nana** is reported to be of superior garden value.

Myrica Gale SWEET GALE

A deciduous shrub of wet soils which, while not outstandingly beautiful, is a part of the native landscape and deserves to be used in highway development. In nature it becomes a five-foot plant having numerous upright stems which carry wedge-shaped leaves.

MYRICA PENNSYLVANICA (*M. caroliniensis*) NORTHERN BAYBERRY

A familiar, slow-growing, upright-branched, native, deciduous shrub of barren soils, best known for its wax-coated, winter-decorative, gray berries, much sought by birds. It will develop well as a spreading, symmetrical specimen plant, but is best suited for covering open sterile wastes as it does in nature.

Neillia sinensis TUBE NEILLIA

While no hardier of top, this thin-branched, dark-stemmed, toothed-leaved, more open plant would well replace *Stephanandra* as a deciduous shrub in mixed plantings. Also, where it is hardy enough to reach maturity, it would seem better than *Physocarpus* because of its terminal clusters of pink flowers in June.

Nemopanthus mucronata MOUNTAIN-HOLLY

Deciduous, open, upright, native shrub with interesting pendent red fruits in August, and leaves turning yellow in autumn. It has value because of its liking for damp soils and ability to withstand some shade. A plant for the wild garden or roadside. Fruit eaten by birds.

New Jersey Tea — See Ceanothus

Nyssa sylvatica TUPELO

An upland species of a genus of southern swamps which will in time grow into a tall, clean-boled tree with interesting bark. It is of value for roadside or other semi-wild planting at any age because of the high autumn color of its lustrous leaves, but is difficult to transplant in larger sizes.

Oak — See Quercus

Opuntia humifusa (*O. compressa*) (*O. vulgaris*) (*O. Rafinesquei*)
HARDY PRICKLY PEAR

This native cactus of the New England coastal area has rockery or wild garden interest.

OXYDENDRUM ARBOREUM SOURWOOD

Though capable of growing much taller in the wild, this deciduous plant of sour soils is usually seen in cultivation as a small tree less than thirty feet tall, or as a very large, upright shrub. Its garden value depends to some degree on the July-borne drooping panicles of white flowers, but more on the scarlet autumn color of the leaves. Old plants taken from the wild must, as a rule, be cut to the ground and the top regrown. It can withstand some shade.

PACHISTIMA CANBYI

This foot-high, American, evergreen shrub has its branches covered with inch-long, persistent leaves. A superior plant for massing as ground cover in well-drained areas, or for specimen plants in rock gardens. It can withstand the light shade of open woods.

PACHYSANDRA TERMINALIS JAPANESE SPURGE

A familiar, low, creeping, ground cover which fills up to form neat, level masses of shining green foliage. It is really satisfactory in shade only. Also, it can withstand drought but needs a fairly deep soil which has not been usurped by the fine roots of such trees as Maples. For such situations an occasional top-dressing of loam or compost is necessary.

PAEONIA SUFFRUTICOSA TREE PEONY

Though capable of building up a woody framework a yard or so through, this species and its varieties bloom better, and remain more symmetrical, if kept low through annual removal of older wood to ground level. Thus treated, they remain plants for the herbaceous border or for the low edges of shrubberies. Varietal plants grafted on the woody type or on herbaceous roots are sure to give trouble in the way of foreign suckers or disease. Own-root plants are immeasurably superior. As a result of long cultivation, hundreds of varieties are offered and selection becomes a matter for personal taste.

Pagoda-Tree — See Sophora

Parthenocissus quinquefolia var. Engelmannii ENGELMANN CREEPER

A somewhat refined form of the Virginia Creeper. A coarse, deciduous vine which climbs vigorously over walls, tree trunks, and ledges. The five-parted leaves take on brilliant scarlet autumn coloration. Bluish-black fruits in September and October.

PARTHENOCISSUS TRICUSPIDATA (*Ampelopsis Veitchii*)
JAPANESE CREEPER (BOSTON IVY)

While not generally hardy north of Boston, this popular, vigorous but neat appearing, deciduous vine has few equals for wall covering, especially under city conditions. Brilliant autumn foliage coloration. Fruits blue-black in early autumn. Var. **LOWII**, GERANIUM CREEPER, is small leaved with fine stems and scattered foliage which is brilliant in autumn. A satisfactory cover for low, rough masonry.

Partridge-Berry — See Mitchella

Peach — See Prunus

Pearl-Bush — See Exochorda

PENTSTEMON SCOULERI

This one-foot plant of dense habit is one of the best of the several woody Pentstemons which find a place in rock gardens. It has relatively large, lilac flowers in midsummer.

Periwinkle — See Vinca

habit. A coarse plant suitable for windbreaks and other distant planting. In cultivation, it has proved useful in damp situations, in areas of poor soil, and for seaside planting. On the whole, it is not considered to be a long-lived tree in eastern North America.

PINUS RESINOSA RED PINE

Though its primary economic importance is as a timber tree, some one hundred feet in height, this plant in its younger stages has distinct ornamental value. It is of fairly rapid growth, has a foliage aspect of soft, dark green, and is usually well furnished at the base. It transplants easily, seems indifferent to the type of soil in which it is placed, and can be used either in massed background planting or as a specimen. As it grows older, it opens up and takes on a dark, rough appearance.

PINUS STROBUS WHITE PINE

This New England representative of the Soft Pines has been of considerable economic importance as a timber tree, but at no time in its life history is any specimen ever lacking in true landscape interest. Though everyone is familiar with its garden value as a young plant, few have appreciated how in its old age it displays its rugged trunk and extends its horizontal branches against the sky to build up much the same stratified appearance for which the Cedars of Lebanon are so famed. Though valuable for screens and hedges while young, the final beauty of the mature tree would seem to be its greatest contribution to the New England landscape. It has serious insect and disease enemies. Var. **FASTIGIATA** is a satisfactory plant of narrow, upright habit which would seem to be better than the type for certain tall screen effects.

Pinus sylvestris SCOTS PINE

A variable species which seldom grows up into a symmetrical plant and has little claim to garden value beyond the reddish effect of its heavy branches. It is sometimes planted because of its ability to resist smoky city conditions and also to populate light, sandy soils. In this regard it is probably no better than the native *Pinus rigida*, which in most instances builds up a finer, straighter bole, fully as ornamental as that of the exotic species which is replacing it. For strictly formal screens or for odd specimens, the Scots Pine has two interesting upright forms. Var. WATERERI, a relatively low-growing, dense, columnar form with short, steel-blue leaves is of value in the rock garden. A taller-growing, narrow, pyramidal plant with an erect main stem and upright branching is var. FASTIGIATA.

Pinus Thunbergii JAPANESE BLACK PINE

A rapid-growing, wide-spreading tree one hundred feet or more at maturity, with an irregular head and brilliant green foliage. For inland situations it has proved to be definitely not hardy, but it is reported to be a splendid thing on exposed, wind-swept seashore places on Cape Cod.

X PLATANUS ACERIFOLIA LONDON PLANE-TREE

This hybrid is the so-called Oriental Plane of the trade, which has been much used as a street tree because of its ability to resist smoke, dust, and other city conditions. As a shade tree it does not inhibit satisfactory growth of grass at its base. It also is reported to do well near the sea. Though not so hardy as its American parent, *P. occidentalis*, it will, in warmer sections, get up to some eighty feet or more and display the same mottled bark.

Plum — See Prunus

POLYGALA CHAMAEBUXUS

A creeping, evergreen, rock-garden shrub which reaches a height of some nine inches. It has small shining leaves and flowers with white wings and yellowish keels.

POLYGONUM AUBERTII China Fleecevine

A vigorous, graceful, thin-wooded, clambering or slightly twining, deciduous vine having dense, bright-green foliage. The upper portion of the plant is covered in late August and on into the autumn with fleecy, six- to eight-inch panicles of white flowers turning pinkish. There are occasional flowers earlier in the season. It will not climb a wall but requires training on support. Much new growth comes up from the base in the spring.

POPULUS LASIOCARPA Chinese Poplar

Rather a rare Chinese species which grows into a round-headed tree some sixty feet high, and is made noticeable by its foot-long leaves with red midribs and petioles. It has proved difficult of propagation.

Populus Maximowiczii Japanese Poplar

A quick-growing, hundred-foot, Asiatic Poplar which has a thick, gray-barked bole, symmetrical head, and attractive foliage.

Potentilla fruticosa Shrubby Cinquefoil

A variable, native, deciduous shrub which ranges in habitat from very dry to quite wet situations. Its straggling habit, silky, compound leaves, and yellow summer flowers give it some value for development of large sunny banks or slopes in semi-wild areas. Varieties with white flowers have been described.

Prickly Pear — See Opuntia

Privet — See Ligustrum

Prunus cerasifera var. Pissartii Purpleleaf Plum

Analagous to the red-leaved peach, this twenty-five-foot, purple-leaved form of a commonly used plum understock has pink flowers and wine-red fruits. Because of its color and the cultural difficulties of plums in general, it is of limited value.

Prunus Maackii Amur Cherry

A very hardy, forty-foot tree with interesting light brown, flaky bark and pleasing clusters of small white flowers. A supposed hybrid of this species is sold in the West under the name of "Mayday Tree."

Prunus maritima Beach Plum

Though in character with the wild landscape of areas near the sea, this and a number of inland plants such as *Prunus Besseyi* seem to be valuable chiefly for the potential economic possibilities of their fruits. In the wild, they are hosts to serious diseases and destructive insects.

PRUNUS PERSICA Flowering Peach

Though little different in aspect and, because of grafting on indifferent peach seedlings, seldom longer lived in cultivation than orchard peaches, there seems to be some evidence of greater fundamental hardiness on the part of the strictly ornamental varieties. Probably an improvement in propagation methods, and a pest control program comparable to orchard sanitation would help these plants of such intense flower color to gain some of the popularity which they merit. As to hardiness, they may be expected to thrive wherever peaches are grown successfully. Var. **atropurpurea** has purple leaves. Var. **ALBO-PLENA** has semi-double flowers of the whitest white. Var. **CAMELLIAEFLORA** has semi-double, deep red flowers. Var. **DUPLEX** has double pink flowers.

Prunus pumila var. depressa PROSTRATE SAND CHERRY
A prostrate plant which has narrow leaves and edible black fruits. Of limited possibilities as a ground cover, or for use in the large rockery.

PRUNUS SARGENTII (*P. serrulata* var. *sachalinensis*) SARGENT CHERRY
Evidence of the hardiness and specimen value of this Cherry is given by a tree which stands on the campus at Amherst. Grown from Oriental seed received in 1877, it is now some fifty feet tall, sixty-five feet in spread of top, and two feet in trunk diameter. The display of short-lasting pink flowers in late April or early May, pleasant foliage, and freedom from pests — all taken together with natural vigor, make for the usefulness of this plant as a shade or roadside tree in less confined plantings.

PRUNUS SERRULATA, "AMANOGAWA" AMANOGAWA
A somewhat tender Cherry with semi-double, pale-pink flowers. This variety is distinctive because of the columnar habit which results from the erect position of every twig and branch.

PRUNUS SERRULATA var. FUGENZO ("*J. H. Veitch*") ("*Kofugen*")
With longer-lasting, double, pink flowers hanging on slender stems, this variety is one of the better known of several similar Oriental garden forms related to the Sargent Cherry. It may, however, be considered less hardy both as a plant and as to reliability of bloom.

PRUNUS SUBHIRTELLA HIGAN CHERRY
A hardy, round-topped, bushy tree up to some thirty feet, bearing a profusion of single pink flowers before the leaves in early spring. Var. **ASCENDENS**, with simpler branching, builds up into a tree of about twice the size of the type. Var. **PENDULA** is a weeping form which has been much abused by faulty propagation. If taken as selected seedlings or grafted low, as it should be, and trained to a single central leader, the side branches will build up an interesting framework. Top-worked plants of umbrella habit are to be shunned.

PRUNUS TOMENTOSA NANKING CHERRY
A spreading deciduous shrub up to eight or more feet, which in addition to the white or pinkish, late-April flowers has showy red fruits which have some economic importance for preserving and wine-making.

Prunus triloba FLOWERING PLUM
This plant is not to be confused with *P. glandulosa*, the Flowering Almond. Own-root plants of this hardy, enduring species form large, suckering deciduous shrubs. Tree-like specimens produced by the questionable practice of budding on peach or other equally unsatisfactory understocks are usually of short duration. The type being rare, the Flowering Plum is seen commonly in cultivation in the var. **PLENA** which has profuse double white flowers. It is sometimes forced.

Pseudolarix amabilis (*P. Kaempferi*) GOLDEN LARCH
A hardy, Larch-like tree with feathery foliage, turning yellow in autumn, which on subneutral soils gets up in time to one hundred feet or more. In order to secure straight leaders and symmetrical branching, either seedlings

or grafts of true terminal shoots should be used. To be of value, it is best used as an isolated specimen.

PSEUDOTSUGA TAXIFOLIA (*P. Douglasii*) **DOUGLAS FIR**

The Colorado expression of this western timber tree, although not too much at home in New England, has been used extensively for large screens and other situations suitable for towering Spruces and Firs. It is a gawky, unsymmetrical plant while very young and as a result young plants have often been sheared into shape. Such trimmed specimens have too often been ineptly substituted for slower-growing material, only to grow out of hand in subsequent seasons. Then, too, close shearing of seedling plants usually makes for crippled lower branches as the plant approaches maturity. Here is a plant which seems to vie with Taxus and Tsuga for large screens or hedges in shady places. Seedling blocks of Douglas Fir show considerable variation, and in Europe numerous varieties have been determined on the basis of color or growth habit.

Pyxidanthera barbulata

A low, creeping, evergreen shrub of the east coast pine barrens. Of interest in moist, sour, rockery spots because of its mat of fine leaves and spring-borne white flowers.

QUERCUS ALBA **WHITE OAK**

Though lacking in spectacular features as a young plant, this familiar native tree, with its stocky bole and heavy-branched, far-spreading crown, forms in maturity one of the distinctive features of our landscape. It is of value as a specimen tree. Long-established plants are difficult to transplant.

QUERCUS BOREALIS (*Q. rubra*) **NORTHERN RED OAK**

A native tree which in the wild varies in stature and habit according to differences in soil and degree of crowding to which it is subjected. As a specimen on deep soil, it can become one of the tallest of our oaks, with a broad top and nearly erect main branches. Its lustrous, sharp-lobed leaves turn red in autumn.

QUERCUS COCCINEA **SCARLET OAK**

A more easily transplanted, native, deciduous tree which does well in lighter, drier soils, and at maturity spreads out a broad open head some eighty feet in height. Its deep-cut leaves change from the bright green of summer to brilliant scarlet in autumn.

QUERCUS IMBRICARIA **SHINGLE OAK**

A useful sixty-foot tree of deep soils which grows up through a juvenile pyramidal habit to become a round-topped mature specimen. Its narrow shining leaves — unlobed, unlike those of most other Oaks — turn a reddish brown in autumn.

QUERCUS PALUSTRIS **PIN OAK**

A straight-trunked tree some sixty feet or more in height, having small, sharp-lobed leaves and a characteristic downward slant to its lower branches which terminate in somewhat pendulous twigs. Though thought of as a plant for moist land, it will develop numerous leaders and quickly spread out a broad low crown if the water table is too high. Here is a most satisfactory street or park tree for any area of deep soil.

QUERCUS ROBUR var. FASTIGIATA **FASTIGIATE ENGLISH OAK**

Made fine-textured by small, rounded-lobed leaves, and columnar in aspect by the erect habit of its branching, this plant is a superior alternative to the

PHELLODENDRON AMURENSE AMUR CORK-TREE

A species which, except for the noticeably corky bark of older specimens, may be considered to be of less value than *P. sachalinense.*

PHELLODENDRON SACHALINENSE SAGHALIN CORK-TREE

Though of no particular interest while young, this Asiatic species in its later years forms a tall, broad-topped specimen with compound leaves which turn a lemon-yellow in autumn. Its ability to resist trying growing conditions makes it one of the few introduced trees of definite exotic aspect which seem to be increasing in popularity.

PHILADELPHUS MOCK-ORANGE

This is a large group which is much confused horticulturally now that so many hybrid forms have appeared on the market. The following critical selections give a working list which covers the range both as to floral and vegetative characters. For an extended analysis, see the Arnold Arboretum Bulletin of Popular Information for June 15, 1936.

PHILADELPHUS CORONARIUS SWEET MOCK-ORANGE

The old-fashioned Mock-orange with single, fragrant, June flowers which are ivory in color and something over an inch in diameter. A thin-twigged shrub (up to ten feet or more) for mixed planting or unclipped screens and hedges. Shearing of tops will interfere with flowering unless done but once a year and that in late June just after flowering.

X PHILADELPHUS CYMOSUS, "NORMA"

Also an upright shrub, but looser, less tall, and not as top-hardy. Its slightly larger, fragrant white flowers in June are for the most part single; a few, double.

X PHILADELPHUS LEMOINEI, "AVALANCHE"

A hybrid of more drooping growth habit, with perhaps half the ultimate height of *P. coronarius.* Relatively small, single, fragrant, white flowers in June. Not always quite top-hardy in inland New England.

X PHILADELPHUS MAXIMUS

A tall, hardy, upright, relatively small-flowered, scentless, white hybrid capable of reaching a height of thirty feet. Obviously nothing for the intimate garden, but useful in some groupings.

X PHILADELPHUS SPLENDENS

A hybrid of rounded growth, making a large, well-furnished, mounded growth-mass of somewhat greater ultimate height than *P. coronarius.* Its scentless flowers are somewhat wider than those of *P. coronarius* and slightly four-angled.

X PHILADELPHUS VIRGINALIS, "VIRGINAL"

An upright but not always too symmetrical plant of perhaps two-thirds the ultimate height of *P. coronarius.* It has large, mildly fragrant and semi-double flowers in June, with occasional bloom thereafter. Less hardy than *P. coronarius.*

Phlox bifida SAND PHLOX

A much-branched, woody-based, creeping Phlox which has hairy stems and pale purple flowers with cleft petals. Useful in some rock gardening. A totally different plant which is often erroneously sold under this name is *Ruellia ciliosa.*

Phlox subulata MOSS PHLOX

An almost too common, woody-based, fast-creeping, spring-flowering Phlox. It may be had in numerous color forms some of which probably belong to other species. The chief interest in this group at present is being directed toward several varieties, such as **VIVID**, which do not spread rapidly and hence become of value in the rockery of limited size.

Photinia villosa var. laevis

A large, open, dark-barked, deciduous shrub some fifteen feet through if unpruned, which is of value chiefly because of heavy autumn crop of small, red, long-persistent fruits. Something for the backs of large groupings or for use in semi-wild roadside development.

Phyllodoce coerulea

A depressed, six-inch, heath-like native plant with June-borne purple flowers, turning bluish, which can be used in shaded rock-garden situations.

Phyllodoce empetriformis

A western species of like vigor but showing slight differences in branch-habit and flowers.

X Phyllothamnus erectus

A hybrid evergreen shrub of some twelve inches, which has narrow shining leaves and round, bell-shaped, pink flowers. A rock-garden plant.

Picea Abies (*P. excelsa*) NORWAY SPRUCE

A well-known, quick-growing conifer which is now being displaced rapidly in large plantings by other finer large spruces and on more limited areas by its own dwarf or slow-growing varieties. It has little place in fine gardening and should be relegated to use in shelter belts, coarse hedges, or other rough purposes. It is not considered by some to be as valuable for Christmas trees as Balsam Fir because of quicker needle drop. It is a common host to a gall-forming aphid. Var. **CLANBRASILIANA** is a slow-growing, compact, rounded bush rarely exceeding eight or ten feet. Var. **GREGORYANA** is a dwarf, dense, conical form usually seen as a two- or three-foot plant. Var. **MAXWELLII** is a dense, round, flat-topped form which, though spreading to a diameter of several feet, seldom exceeds more than two feet in height. It sometimes produces aberrant coarse shoots which, if propagated, produce stronger-growing plants of the same habit. Like other dwarf forms of Norway Spruce, this is subject to attacks of red spider mite. Var. **NIDIFORMIS** as a young plant is round, bushy, depressed at the top. Var. **PYGMAEA** when young forms a dense cone. Vars. **PROCUMBENS**, **REPENS**, and **TABULIFORMIS**, unlike some of the other dwarf forms which later send out prostrate growth, spread from the very start and can form creeping mats if given room enough on the right sort of location. Listed also are narrow fastigiate forms and weeping forms.

PICEA ASPERATA

One of the more recently introduced Chinese spruces, which makes a dense, broad, pyramidal tree with an ultimate height of sixty to one hundred feet. Its dark-green foliage and superior garden aspect make it a likely substitute for the Norway Spruce in large plantings.

Picea Engelmanni ENGELMANN SPRUCE

In its native state in western North America, this spruce may develop into a tree one hundred and fifty feet tall. However, in gardens it becomes usually a slow-growing, densely pyramidal plant with its lower branches, in large specimens, resting on the ground. Var. **GLAUCA**, which may be picked out of almost any lot of seedlings, develops into an agreeable blue spruce which is generally considered to be more pleasing than the far too common blue form of *P. pungens*.

PICEA GLAUCA (*P. alba*) (*P. canadensis*) WHITE SPRUCE

A native northern, large spruce which has bluish aromatic foliage. In cultivation it shows compact habit in much younger plants than does the commonly planted foreign *P. Abies*, and is thus more suitable for tubs and window boxes. It remains in maturity a well-furnished pyramidal tree which can withstand varying soil conditions. Also, it stands up under repeated pruning when used as material for tall hedges. Var. **Conica**, DWARF ALBERTA SPRUCE, is a slow-growing, dense, regular-shaped, pyramidal tree with soft bluish-green or bright-green foliage, which will, in time, grow many feet in height and retain its symmetry if protected from infestation of red spider mite and not so located as to be burned by the sun and wind of late winter. A plant of value only in the rock garden or under special circumstances for hedge making.

PICEA GLEHNII SAGHALIN SPRUCE

In cultivation, a slow-growing, narrow, pyramidal tree with small, shining, dark-green foliage. It is suggested here as a possible hardier substitute for *P. orientalis* in exposed situations.

PICEA KOYAMAI KOYAMAI SPRUCE

A recently introduced, narrow, pyramidal tree growing to some sixty feet in height. In general aspect it very nearly resembles *P. Abies* and is rapidly coming to be considered as a substitute for the type of that species.

PICEA OMORIKA SERBIAN SPRUCE

If planted in rich, well-drained soil, this Balkan tree will grow to a height of sixty to one hundred feet, retaining its narrow pyramidal habit. The foliage, with parts of both surfaces exposed because of the upright and spreading nature of the branching, gives a distinctly two-toned effect of white and green. Rated as one of the most beautiful of all spruces.

PICEA ORIENTALIS ORIENTAL SPRUCE

In cultivation, this plant is of relatively slow growth for the first thirty or forty years, and usually appears in gardens as a broad-based tree, the numerous branches of which turn up at the ends to form a somewhat tapering column. It is hardy if given a soil which does not dry out in winter and if so located that the short, shining, dark-green leaves are not given full exposure to winter sun and wind. In its native site it grows to be as high as one hundred and fifty feet.

Picea pungens COLORADO SPRUCE

The type is the green-leaved Colorado spruce which has been so much overplanted. There is very little to recommend it except that it seems to be very durable near salt water. In cultivation, both the type and its varieties very often lose their lower branches through attack of a canker-forming fungus for which, as yet, no curative measures have been discovered. This species breaks into a number of color forms and varieties displaying differences of habit. Var. **ARGENTEA** is the silver form which is distributed through the trade as Koster's Spruce. Under this name, also, have been distributed a great many indifferent seedlings. The true variety **Kosteriana** is a weeping form with bluish foliage. All of these blue forms of spruce are, because of their color, difficult to group, and their handling requires more consideration than has been shown in the past.

PIERIS FLORIBUNDA MOUNTAIN ANDROMEDA

A broad-leaved, native, evergreen shrub closely approaching *Kalmia latifolia* in habit and aspect, but of smaller ultimate size and with smaller leaves. It also differs from Mountain Laurel in having white "Lily-of-the-Valley" flowers in somewhat erect panicles in late April or May. It is lighted up in winter by the green buds of the following season's flowers.

PIERIS JAPONICA JAPANESE ANDROMEDA

A broad-leaved, evergreen shrub which, compared to *P. floribunda*, is less hardy, has glossier, more bunched foliage, and more drooping flowers, and will where hardy make a larger plant.

PINUS CEMBRA SWISS STONE PINE

Though in old age this plant may break out into a round-topped, picturesque head, it is usually seen in gardens in its slow-growing, densely pyramidal, juvenile state. Its foliage, which retains a dark-green color throughout the year, is borne on rather stiff, horizontal branches. A satisfactory tree for limited areas if given sufficient soil moisture.

Pinus densiflora var. umbraculifera

This variety of the Japanese Red Pine is often seen as a small, low, flat-topped plant resembling *P. Abies Maxwellii* in habit. In time, however, it will take on a very open and picturesque aspect by becoming an eight- to ten-foot shrub with half a dozen crooked, ascending, reddish-barked branches, each of which is terminated by a flattened cluster of smaller stems. It can probably be used to advantage only at the top of a very large rockery or on rough, stony hillsides.

PINUS KORAIENSIS KOREAN PINE

Though listed as a tree capable of growing to a height of a hundred feet, this species in gardens may be looked upon as a plant of pyramidal habit, horizontal branching, and slow growth suitable for restricted situations. It is a five-leaved pine somewhat more stocky in aspect and with darker foliage than our native *Pinus Strobus*.

Pinus mugo SWISS MOUNTAIN PINE

This is an exceptionally variable species (broken up by the botanists into four general groups on the basis of cone characters) both in the wild and in cultivation because of the fact that nearly all available stock has been grown from seed. Numerous selections made at various times have been carried on in a very limited way by means of vegetative propagation. Probably the popular conception of the so-called Mugho Pine, and the thing which the trade intends to sell as **Pinus mugo var. Mughus**, is a dwarf, rounded, or low-growing plant. If such dwarf plants are wanted, one must secure vegetatively propagated forms, such as var. COMPACTA, the HILL MUGO PINE, or the variety SLAVINII developed by the Rochester, New York, Park System, or take his chance on being able to select desired forms from large blocks of seedling plants. It is a welcome host to the pine leaf scale.

Pinus nigra AUSTRIAN PINE

When young, this variable species is a rather regular, quick-growing plant with long, stiff needles. As it grows toward maturity, it reaches out rather dark, heavy, irregular branches in a grotesque but not altogether unpleasant most unsatisfactory Lombardy Poplar. Despite the belief that it is tender, there is a fine specimen of some forty feet or more luxuriating on a moist slope in Topsfield, Massachusetts. Then, too, small plants of but a few feet in height have in recent years withstood sub-zero temperatures successfully.

QUERCUS VELUTINA BLACK OAK

A quick-growing, thick-boled, native, deciduous tree of gravelly soils. In maturity it becomes an open-headed, hundred-foot specimen of value in natural plantings. Its blunt-lobed, dark-green leaves turn orange or dull red in autumn.

Raspberry — See Rubus

Redbud — See Cercis

Rhamnus Frangula GLOSSY BUCKTHORN

A small, deciduous tree or large shrub which can add interest to roadside or natural plantings in the open because of round, dark-green, shiny foliage, and clusters of red fruits turning black upon ripening in late summer. Its foliage is clear yellow in autumn. Larger leaves and fruits may be had by securing the var. **LATIFOLIA.** Fruits interesting to birds.

Rhamnus pumila DWARF BUCKTHORN

A round-leaved, black-berried, deciduous shrub which, because of its procumbent branches, is suitable for the large rockery.

RHODODENDRON

With its hundreds of species and thousands of garden hybrids, most of which are not hardy throughout New England, this genus very nearly defies tabloid treatment. Nevertheless, an attempt is here made to evaluate those forms which have found general favor within the area under consideration. Such conservative treatment can be made, however, with no sense of finality because undoubtedly some of the newer Asiatic species and varieties may prove their worth for general culture in the warmer sections near the sea. Numerous forms are now under test, promising among which are the hybrids of *R. Fortunei.* Then, too, unmentioned here are many other horticultural varieties based on floral color, or similar features, attractive to varying personal taste. For purposes of indexing, the evergreen Rhododendrons, the deciduous Azaleas, and the intermediate *R. mucronulatum* are not listed separately. Such horticultural differences are, however, explained in the text.

RHODODENDRON, ALPINE ROSE HYBRIDS

The plants in this group are hybrids of the European *R. ferrugineum* and *R. hirsutum* with various other species. Though when happy they will grow up eventually to be neat, four- or five-foot, evergreen plants, their compact habit makes them adaptable for culture in the larger rock garden. **X R. ARBUTIFOLIUM**, three-inch leaves and pinkish-lilac, three-quarter-inch, bell-shaped flowers in June; **X R. LAETEVIRENS** (*R. Wilsoni*), magenta-rose flowers about twice the size of those of *R. arbutifolium*, June and July; **X R. MYRTIFOLIUM**, plant somewhat more vigorous, leaves slightly shorter and brown beneath, flowers lilac-pink and medium-sized for the group.

RHODODENDRON ARBORESCENS SWEET AZALEA (SMOOTH AZALEA)

Unlike the later flowering *R. viscosum*, this hardy, native, deciduous shrub is an upland plant which in the wild sometimes reaches a height of twenty feet. The one- to two-inch, heliotrope-scented, white flowers of the type plant open after the leaves in June along with those of *R. calendulaceum.* Rated as the best of the native white Azaleas.

Rhododendrom arbutifolium — See Rhododendron, Alpine Rose Hybrids

RHODODENDRON CALENDULACEUM (*Azalea calendulacea*) FLAME AZALEA

A native decidous shrub with a possible height and spread of ten feet. In the wild its flowers, which are generally thought of as orange and about two inches across, come about one to two weeks after those of *R. roseum.* Wild plants of this species show individual flower-color variation from yellow to scarlet as well as variations in size and form of flower. It is one of the parents of the Ghent Hybrid Azaleas which despite larger flowers could, for the American garden, be dropped in favor of selected clons of this wild parent plant.

Rhododendron canadense (*Rhodora canadensis*) RHODORA

A low (one to three feet), somewhat gaunt inhabitant of moist woods or swamps which, though lacking the garden value of many other species, has a definite place in wild, informal planting because of bud hardiness of its May flowers, and sentimental association.

RHODODENDRON CAROLINIANUM CAROLINA RHODODENDRON

As seen in cultivation, this evergreen species is a broad, compact shrub some four or five feet in height. Foliage is relatively small and of reddish cast in winter. The flowers, usually pink, appear in late May. With white flowers and of somewhat less vigor, var. **ALBUM** is rated by some as having greater garden value than the type. Both forms are satisfactory for forcing.

RHODODENDRON CATAWBIENSE CATAWBA RHODODENDRON

A handsome, hardy, large-leaved, evergreen species growing ultimately to some six to ten feet in spread and height. Its only unsatisfactory property is the purplish flower color which limits its use in garden groupings. Its better features of habit and foliage have been transmitted to numerous, often less hardy, hybrids of more pleasing and usable floral color. Of slow growth and compact habit, var. **COMPACTUM** is a distinct natural strain discovered by Mr. Harlan P. Kelsey.

RHODODENDRON, EVERGREEN HYBRIDS

The following list gives the combined opinion of many New England observers as to the more dependable and pleasing of the numerous garden hybrids: **"ALBUM ELEGANS"**, late white flowers; **"ATROSANGUINEUM"**, early red; **"BOULE DE NEIGE"**, early white; **"CATAWBIENSE ALBUM"**, white; **"CHARLES DICKENS"**, red; **"DELICATISSIMUM"**, rose-tinged white; **"EVERESTIANUM"**, lilac; **"LADY ARMSTRONG"**, rose; **"MRS. CHARLES SARGENT"**, deep rose; **"PURPUREUM GRANDIFLORUM"**, purple.

X Rhododendron gandavense GHENT HYBRID AZALEAS

This group includes a host of neat-growing garden varieties, most of which, because of lack of hardiness, have not come into garden use in New England. Apparently, success with their outdoor culture is dependent more on ample moisture supply during the normally dry periods of summer than on degree of winter cold. Own-root plants are considered to be superior to grafts. Mr. P. M. Koster, writing in House and Garden Magazine, suggested the following list for trial; **"Daviesii"**, large single white flowers; **"Dulcinee"**, single salmon-red with yellow blotch; **"Pallas"**, single red; **"Unique"**, single, deep, bright yellow; **"Bijou de Gandbruges"**, double pink; and **"Raphael de Smet"**, double rose.

RHODODENDRON INDICUM var. BALSAMINAEFLORUM BALSAM AZALEA

A spreading, almost evergreen plant of extremely slow growth, for sheltered rock-garden situations. Small leaves and double salmon-red flowers in June or early July.

RHODODENDRON JAPONICUM JAPANESE AZALEA

A much-branched deciduous shrub to some six feet. Like *R. calendulaceum*, its seedlings, without hybridization, display individual flower color variations ranging from yellow to red or salmon-rose, late in May along with *R. roseum*. It endures less acidity than some other species. Vegetative propagation of outstandingly distinct individual clons would extend to inland New England a group of high-colored, large-flowered Azaleas with the garden value of the more tender Mollis hybrids. One such clon is var. **AUREUM** which is a fine yellow.

X Rhododendron Kosterianum, "Miss Louisa Hunnewell"

An Azalea, the type of which was a rich, orange-yellow flowered, hardy hybrid between *R. japonicum* and *R. molle*. True plants of such a hybrid are those propagated vegetatively from portions of the original stock which, in this instance, may not now be in existence. Unfortunately, the material now offered is of seedling origin and may often contain varying *R. japonicum* and *R. molle* seedlings.

Rhododendron laetevirens — See Rhododendron, Alpine Rose Hybrids

Rhododendron lapponicum LAPLAND RHODODENDRON

A plant from Arctic tundra and mountain tops farther south, this species is something for the understanding care of the enthusiastic rock gardener. A one-foot shrub with tiny purplish flowers, it probably needs a cool, moist, acid root-run and some shade.

RHODODENDRON MAXIMUM ROSEBAY RHODODENDRON

The well-known, tall-growing (seldom above fifteen feet in the North), large-leaved, native species which in mass planting is most capable of giving fine screen and evergreen mass effects. Its sparsely borne, whitish inflorescence, which does not open much before July, is relatively small, and often hidden by new growth. Wild, single-stemmed plants are usually open in habit and straggly.

Rhododendron minus PIEDMONT RHODODENDRON

Belying its name, this species is loose and straggling, often growing to a height of ten feet or more. Because of its hardiness, it is valuable for woodland planting where the magenta color of its late June flowers will not seem unpleasant. Out of flower, it has the appearance of a coarse form of *R. carolinianum*.

RHODODENDRON MUCRONULATUM

The type of this tall, gaunt, deciduous shrub differs from that of the somewhat evergreen *R. dauricum* in having larger, brighter flowers, larger leaves, and in being somewhat earlier in its blooming time in late March or early April. However, in cultivation the two species seem to be mixed together and almost impossible of separation. Planted in wood-edges or in large mixed groupings, it can be made to light up the otherwise cheerless post-winter landscape with its not unpleasant magenta flowers. So early does it bloom that open flowers are often frozen.

Rhododendron myrtifolium — See Rhododendron, Alpine Rose Hybrids

RHODODENDRON OBTUSUM var. KAEMPFERI (*Azalea Kaempferi*) TORCH AZALEA

In New England, a broad, much-branched, deciduous shrub up to six feet or possibly more, which blooms in a glowing mass of vivid carmine-pink, or scarlet-pink, about the end of May. The show of flowers can be protected against too quick fading by planting in a location which is shaded for a part of the day. It is severely injured by winter temperature below 20° below zero.

Rhododendron racemosum

A semi-evergreen, leggy, flopping, small shrub (sometimes up to three feet) suitable for sheltered wall or rock-garden planting. Its flowers, pink to white, resembling those of trailing arbutus, appear towards the end of May. Both Forrest and Rock have collected hardier strains which are beginning to become available.

RHODODENDRON ROSEUM MAYFLOWER AZALEA (DOWNY PINXTERBLOOM)

A multiple-stemmed, bushy, deciduous native shrub some two to eight feet through. Clove-scented, bright pink flowers open with the leaves in May. In cultivation it may be considered as superior to *R. nudiflorum* because of more showy flowers, extreme hardiness, and indifference as to soil requirements.

RHODODENDRON SCHLIPPENBACHII ROYAL AZALEA

An upright-growing, distinctive Azalea with large deciduous leaves in whorls of five; pale to rose-pink, two- to three-inch flowers in small clusters in late May; and foliage yellow to crimson in autumn. It has at times proved difficult in cultivation but is a splendid thing when suited ecologically.

RHODODENDRON SMIRNOWII SMIRNOW RHODODENDRON

A woolly-leaved, hardy, evergreen shrub of somewhat less rapid growth rate than *R. catawbiense*. The felted undersurfaces of the leaves discourage lace bugs. Flowers rose or rosy-purple in June along with those of *R. catawbiense*.

RHODODENDRON VASEYI PINKSHELL AZALEA

A tall, hardy, upright, deciduous shrub of somewhat irregular branch-habit, with clear rose flowers freely borne before the leaves in May. Foliage takes on a high color in autumn. Rated as one of the finest Azaleas for general natural landscape planting.

RHODODENDRON YEDOENSE var. POUKHANENSE KOREAN AZALEA

A reliably hardy, deciduous or semi-evergreen plant which in full sun tends to remain a compact, low shrub, but becomes more straggly in shaded situations. Its profuse, single, lilac-purple flowers of mid-May have distinct garden value if the plants are placed to bloom by themselves.

RHODOTYPUS SCANDENS (*R. kerrioides*) JETBEAD

A spreading-branched, somewhat coarse-textured, deciduous shrub with a possible height of some six feet. Single white flowers in May or June, and the following winter-persistent, hard, black fruits, give it claim to garden interest. Beyond that, it has been much used in the past because of its ability to withstand neglect, and its satisfactory growth in trying situations such as the north sides of buildings, or dry, gravelly banks.

RHUS CANADENSIS FRAGRANT SUMAC

A prostrate, deciduous shrub, with occasional upright branches to three feet, which has the ability to cover dry, rocky areas. Its noticeable yellow flowers of early spring are followed by aromatic, toothed leaves which turn orange or red in autumn.

RHUS COPALLINA SHINING SUMAC

Deciduous native shrub or small tree (up to thirty feet), with reddish branches and shining foliage. Its greatest landscape value is in autumn when the foliage turns purplish and the showy crimson fruit clusters are prominently displayed. Useful for roadside planting.

RHUS GLABRA SMOOTH SUMAC

Another native deciduous shrub with an ultimate height of some ten feet. Valuable in the open landscape because of its bright red, fall foliage coloration and scarlet fruiting parts. Fruits attractive to grouse and deer.

Rhus typhina STAGHORN SUMAC

The common, coarse, free-suckering, deciduous shrub of waste areas which typifies the name Sumac in popular usage. Its feathery foliage turns scarlet and orange in autumn. Crimson fruit clusters if washed with hot water yield a palatable decoction resembling lemonade in taste. Several cut-leaved forms are in cultivation. The fruits are attractive to grouse and deer.

ROBINIA KELSEYI KELSEY LOCUST

A tall, deciduous shrub (five to nine feet) with characteristic locust foliage and rose-colored, pea-shaped flowers in May and June, followed later by purple seed pods. A free-suckering plant with ability to form thickets if let run wild on large areas. With care, it can be maintained as an individual shrub.

ROSE

The very magnitude of the field of knowledge concerning Roses and their culture precludes any comprehensive treatment of the subject in a study such as this. Such information is, of necessity, contained in a literature of its own. Nevertheless, it is not possible to consider at all complete any enumeration of woody plant materials which gives no thought whatsoever to the Rose; for, after all, it is a woody plant capable, in several of its numerous expressions, of being something more than an intensively stimulated flower-producing mechanism. In its various phases, it has habit, foliage, stem, fruiting, and other characteristics in common with desirable shrubs and vines of other genera. Hence, the reason for the following admittedly incomplete but not particularly arbitrary selections. Specialized publications and catalogues should be consulted for information concerning Roses, both climbing and bush, for more conventional uses.

Rosa acicularis PRICKLY ROSE

A very hardy bush about three feet in height. Its single pink flowers, some two and one-half inches across, are followed by bright, pear-shaped fruits. For roadside planting and use on other similar large areas.

Rosa arvensis

Very hardy, vigorous, trailing-branched, almost evergreen species which will grow in soil that will support few other Roses. It sends up flowers, white, single, and scentless. A plant for the large rockery or for bank planting.

Rosa blanda MEADOW ROSE

A very hardy, native rose, growing from two to four feet in height in moist soil and spreading freely by suckers. Its single pink flowers are two to two and a half inches across. For semi-wild plantings.

ROSA CAROLINA PASTURE ROSE

A low, suckering shrub about one yard in height, with pink flowers about two inches across. For bank planting and ground cover.

ROSA EGLANTERIA (*R. rubiginosa*) SWEETBRIER

A tall (eight to ten foot), thorny bush which builds up into a compact shrub, with two-inch pink flowers in small clusters along its slender branches, followed by round, orange or scarlet fruits. It makes a fine specimen plant if given ample space, or may be used for hedges or barriers. Like many other species of Roses, it is a parent of numerous hybrids.

Rosa gallica FRENCH ROSE

Full, upright shrub to some four feet, with thorny stems and single, dark pink or crimson flowers two to three inches across, and brick-red fruits. It is one of the parents of the "Hybrid Perpetuals."

"**HYBRID PERPETUAL**" Roses, if given the right sort of pruning, can be of value in shrub borders. These selections are made from among the bushy-growing varieties. "**BARONESS ROTHSCHILD**", double, light-pink flowers; "**BARONNE PREVOST**", large, full, fragrant, rose-colored; "**HORACE VERNET**", large, double, high-centered, crimson; "**JULES MARGOTTIN**", double, carmine, slightly fragrant; "**LOUIS VAN HOUTTE**", large, fragrant, crimson-maroon; "**SUZANNE-MARIE RODOCANACHI**", free-flowering, rosy-cerise.

X ROSE HARISONII HARISON'S YELLOW

An old-time hybrid which has been a favorite shrub or hedge plant for more than a hundred years. It has bright yellow, semi-double flowers in June and black fruits. The plant suckers freely, and is usually seen as a four- to six-foot shrub which is hardier than "Persian Yellow."

ROSA HUGONIS

A large (six to eight feet if allowed to grow naturally), small-leaved, spreading and drooping shrub with prickly reddish stems and single, bright yellow flowers freely borne in May. It needs intelligently directed pruning if it is to be kept as a compact individual specimen.

ROSA NITIDA BRISTLY ROSE

A small plant of some eighteen inches in height, with shining foliage and single pink flowers up to two inches across. Useful in the large rock garden or in masses as ground cover on sunny but not too dry slopes.

X "POLYANTHA" ROSES

A group of hybrids of which the tall (two to three feet), large-flowering sorts also offer material for shrub use. "**KIRSTEN POULSEN**", large, single, light red, everblooming; "**MARIE PAVIC**", white with pink center; "**MRS. R. M. FINCH**", rose-pink, two-inch flowers, everblooming; "**SALMON SPRAY**", salmon-pink, tall-growing, long-stemmed.

ROSA PRIMULA (*R. Ecae* of gardens)

Upright shrub to some six feet in height. Earliest species to bloom, with yellowish-white flowers followed by red fruit. Young foliage aromatic, and stems interesting in winter.

ROSA ROULETTII

A dwarf, hardy, rock-garden form which will start showing its pleasant reddish-pink flowers in its first season from cuttings, and will eventually build up into a compact bush some twelve to fifteen inches through. It seldom sets seed in cultivation. Much stock in the trade under this name is really

Rosa chinensis var. *minima* (*R. Lawrenciana*) which grows more rapidly, has a poorer flower color, sets seed freely, and is otherwise less desirable. *R. Roulettii*, too, will, after study, probably be classed as a form of *Rosa chinensis*.

Rosa rubrifolia RED-LEAF ROSE

A stout, reddish-branched, vase-shaped, six-foot, sparse-blooming plant with reddish leaves and relatively small, bright red flowers. As seen in cultivation, this plant does not branch freely from the bottom and is not suitable for specimen planting.

ROSA RUGOSA

A thick-stemmed, prickly shrub which at maturity becomes some six feet or more in height. It displays rough, leathery, shining foliage and, in nature, a variation in color of the large, all-season, single flowers from purple to white. It has large, showy red or orange, persistent hips in autumn. Satisfactory for informal hedges, roadside, or seashore plantings. It has numerous botanical forms, such as var. **PLENA**, double purple flowers and var. **ALBO-PLENA** with double white flowers, and is also the parent of many garden hybrids. Many hybrids retain the aspect of the type plant but vary in floral characters, such as **"NEW CENTURY"**, large, double, flesh pink; **"NOVA ZEMBLA"**, large, white; **"ROSE A PARFUM DE L'HAY"**, double, dark crimson; **"SARAH VAN FLEET"**, rose-pink, fragrant, everblooming; **"SIR THOMAS LIPTON"**, white; and **"STERN VON PRAG"**, large, double red.

Another group of hybrids of a less rugosa-like aspect includes **"AGNES"**, fragrant amber-gold flowers; **"AMELIE GRAVEREAUX"**, double, dark purplish-red; **"DR. ECKENER"**, semi-double, coppery-rose, and golden-yellow; **"SCHNEEZWERG"**, semi-double, snow-white flowers with center of golden stamens throughout the whole season — a fine, hardy shrub with dark-green, disease-resistant foliage; **"VANGUARD"**, large, double, orange-salmon.

Another worth-while group has all-season bloom of small, fringed flowers in clusters on a type-like plant — **"F. J. GROOTENDORST"**, bright red; **"PINK GROOTENDORST"**, light shell-pink.

There are two trailing rugosa hybrids of value for covering slopes or banks; **"MAX GRAF"**, with handsome foliage and sprays of large, single, pink flowers, rated as the best rose variety for ground cover; and **X R. Paulii** (*R. rugosa* var. *repens alba*), with white flowers and stems up to fifteen feet long. Will grow in any soil.

ROSA SETIGERA PRAIRIE ROSE

A pale-leaved American climbing Rose of considerable vigor, with two-inch, single, pink flowers in July. If used against boulders or on steep pond banks, this plant with its upward and outward spread and late-flowering habit can pile up pleasing natural effects in roadside or wild-garden plantings.

X ROSA, "SKYROCKET"

Because of its straight, upright habit, medium-sized, all-season red flowers, and showy, somewhat persistent autumn flowers, this garden variety offers an outstanding example of the informal planting possibilities of several of the newer everblooming, climbing roses.

ROSA SPINOSISSIMA var. ALTAICA ALTAI ROSE

For garden usefulness, this Rose may be considered as a single, white-flowering counterpart of *R. Harisonii*, to which it is related. It builds up into the same sort of symmetrical, sucker-spreading bush and has similar black fruits.

ROSA VIRGINIANA

A free-blooming, six-foot shrub with shining foliage which turns bright yellow in autumn, and relatively late, two-inch, single, pink flowers in June followed by bright red fruits.

Rosa Webbiana

Shrub of some six feet in height with thin stems bearing yellow prickles. The pale-pink, two-inch flowers are followed by bright red fruits. Useful in shrub borders.

ROSA WICHURAIANA MEMORIAL ROSE

The type plant has long, running branches which, when given no support, advance to cover the ground with mat-like, partially evergreen foliage. Its fragrant white flowers are borne in clusters. It is parent to numerous hybrids of which the following are to be recommended as ground-cover plants for sunny slopes and banks, because of healthy, mildew-resistant foliage. **"ALBERIC BARBIER"** with glossy foliage and fragrant, creamy-white flowers; **"AVIATEUR BLERIOT"** with saffron buds and fragrant flowers fading to white; **"EVERGREEN GEM"**, a prostrate creeping plant with almost evergreen foliage and pale yellow, single flowers, which does well in poor soil; **"FRANCOIS POISSON"** with dark, glossy, almost evergreen foliage on a completely prostrate plant and flowers double white or pale yellow; **"SANDERS WHITE"**, rated as one of the best white climbing Roses for any purpose. Its pure-white, double flowers and disease-resistant foliage make it adaptable for bank planting.

Rubus Cockburnianus (*R. Giraldianus*)

A spreading, flopping Raspberry of value in wild gardening because of winter interest of its whitish stems. It associates itself well with boulders in open places in dark, wooded areas.

RUBUS DELICIOSUS BOULDER RASPBERRY

A rather strong-growing, rampant plant with arching branches which sometimes become nine feet in length. Its white, late-spring flowers are similar to those of *Rosa spinosissima* var. *altaica*. Like the native Raspberry, it can be used in rocky places.

Rubus odoratus FLOWERING RASPBERRY

As seen in cultivation, this native plant is usually a yard-high, upright-stemmed, coarse, deciduous shrub with purplish flowers and a bothersome habit of rapid spread by suckers. Not suitable for the garden but well adapted to broad, wild situations in partial shade.

Russian Olive — See Elaeagnus

St. Johnswort — See Hypericum

Salix alba var. vitellina GOLDEN WILLOW

A tall, spreading Willow which is of garden value only because of the winter effect of its yellow branchlets.

Salix babylonica BABYLON WEEPING WILLOW

This is the most common and the least hardy of several often-confused Weeping Willows. In aspect it has greenish or purplish branches and somewhat upright main stems. Like most Willows, this species will thrive in far drier soil than is generally supposed. Var. **crispa** is an oddity on which all leaves are curled.

X SALIX BLANDA WISCONSIN WEEPING WILLOW

This hybrid Willow, in addition to being more hardy than *S. babylonica*, has wider-spreading main branches and dull green or brown branchlets.

Salix elegantissima THURLOW WEEPING WILLOW

Another Weeping Willow which is hardier and of greater stature than *S. babylonica.*

Salix herbacea PYGMY WILLOW

A dwarf alpine Willow with shining leaves and creeping stems reaching but a few inches in height. Of rock-garden interest only.

Salix humilis PRAIRIE WILLOW

Growing to a height of some eight feet, this somewhat variable deciduous shrub can be used to fill up on dry barren upland areas. Flowers in spring before leaves unfold.

SALIX MATSUDANA var. TORTUOSA CONTORTED HANKOW WILLOW

A somewhat tender-twigged Willow of general upright habit, which has a spiral twist in each of its shining, olive-green branches. It has possibilities for screen planting.

SALIX PENTANDRA LAUREL WILLOW

Though capable of growing into a sixty-foot tree, its green stems, yellow buds, dark, shining foliage, and yellow spring catkins have made this Willow popular as material for large hedges and screens, both pruned and natural.

Salix reticulata

A procumbent, deciduous shrub with gray-green, rounded leaves. Suitable for the large rock garden.

Salix retusa

A prostrate Willow which has small, rounded leaves and smooth stems which root down as they extend. For ground cover or rockery.

Salix tristis DWARF PUSSY WILLOW

Of interest in gardening because of an ultimate height of but eighteen inches and catkins which are prominently displayed before the leaves. It can be used to cover up open spots in dry, upland areas.

Salix uva-ursi BEARBERRY WILLOW

Another prostrate alpine Willow which bears small rounded leaves on short branchlets. A rock-garden plant.

SAMBUCUS CANADENSIS AMERICAN ELDERBERRY

The coarse, sucker-spreading shrub commonly seen in low, moist spots throughout the eastern United States. As seen in the wild, it is attractive when covered in June and July with large cymes of white flowers. In some parts of the country, the purple-black fruits rival those of the blueberry as material for pie-making as well as supplying food to birds. Numerous popular varieties based on color or shape of leaves are in cultivation. It also has pomological varieties such as some of the Adams varieties.

SAMBUCUS PUBENS SCARLET ELDERBERRY

A native deciduous shrub capable of growing to a height of fifteen feet in open places in rocky woods. Valued for the bright red, non-edible fruits which ripen in June. A plant for wild gardening or roadside development. White- and yellow-fruited varieties are listed.

Sambucus racemosa EUROPEAN RED ELDER

This European species is mentioned here because of the fondness of native birds for its bright red autumn fruits. It has been suggested by the Department of Agriculture as harmless bait to detract wild life from fruit crops of economic importance.

Sandmyrtle — See Leiophyllum

Sarcococca Hookeriana var. humilis

An evergreen shrub with narrow, shining leaves, insignificant flowers, and black fruits. A shrub for the large, sheltered rock garden where it may never reach its possible ultimate height of five feet. Not reliably hardy.

Sasa pygmaea CARPET BAMBOO

A root-hardy, spreading Bamboo which in the North gets up to but a few inches in height after being killed back during the winter. It can be used on dry, well-drained areas.

SASSAFRAS ALBIDUM (*S. officinale*) COMMON SASSAFRAS

Either because of its common occurrence in the wild or because of its resistance to transplanting in larger sizes, the landscape value of this familiar, gaunt, native tree has become overlooked. Its green stems, the high autumn color of its various-shaped leaves, and the red-stemmed, blue fruits of September are well known.

Schizophragma hydrangeoides JAPANESE HYDRANGEA-VINE

See note under *Hydrangea petiolaris.*

Scholar-Tree — See Sophora

SCIADOPITYS VERTICILLATA UMBRELLA PINE

An exceptionally slow-growing, dark-foliaged, pyramidal tree suitable for specimen planting or, under some conditions, in screens or groups. It is decidedly unhappy if not given deep, moist, reasonably well-drained soil. Some of the oldest and finest specimens in the United States are to be seen growing on the campus of the Massachusetts State College at Amherst.

Sedum populifolium POPLAR STONECROP

A woody-based Sedum of upright habit which grows to more than a foot in height. A rock-garden plant which displays rounded, toothed leaves and pale pink or white flowers in late summer.

Shadblow — See Amelanchier

Silverbell — See Halesia

Smilax rotundifolia HORSE-BRIER

Thorny, green-stemmed, round-leaved, native, deciduous vine of tangled wood edges and copses. Spreading by underground rhizomes and thus becoming either a pest where not wanted or a boon to the planter of game cover or other wild areas. Young shoots may be eaten like asparagus, and the Indians made a jelly from the roots.

Smoke-Tree — See Cotinus

Snowball — See *Viburnum tomentosum* var. *sterile*

Snowbell — See Styrax

Snowberry — See Chiogenes and Symphoricarpus

SOPHORA JAPONICA CHINESE SCHOLAR-TREE (PAGODA-TREE)

Though capable of attaining greater stature, this green-twigged, deciduous plant with compound, long-persistent leaves and summer-borne, pea-like, white flowers is usually seen in cultivation as a small tree or large shrub of not much over twenty feet in height. Its somewhat exotic aspect does not detract from its value for use in home grounds. A form of columnar habit is listed.

Sorbaria sorbifolia URAL FALSE-SPIREA

A coarse, spreading, deciduous, six-foot shrub which has become naturalized in New England. Hardier than other species of its genus, its long, compound leaves and large, white flower panicles in June or July make it useful for planting in certain half-wild areas. Its white flower-masses have been known to detract rose bugs from more valuable plants.

SORBUS ALNIFOLIA

An upright-branched, round-headed, sixty-foot, deciduous tree having simple, Alder-like leaves which turn orange or scarlet in autumn. The white blooms of May are borne in few-flowered clusters, thus making the September display of fruit less showy than that of *S. Aucuparia.*

SORBUS AUCUPARIA EUROPEAN MOUNTAIN ASH

This commonly planted relative of the Pear, Apple, and Chokeberry may be looked upon as superior, in gardens, to the American Mountain Ash because of its larger and more showy autumn fruits. In addition, its ultimate height is somewhat greater and the leaflets of its compound foliage are more rounded. Having been in cultivation for many years, numerous garden forms based on habit or fruit and foliage characters are listed.

Sourwood — See Oxydendrum

Spicebush — See Lindera

Spindlewood — See Evonymus

SPIRAEA BULLATA

A dwarf Spirea having upright branches which reach to an ultimate height of but eighteen inches. A rock-garden shrub with small, rounded leaves and clusters of rosy-pink flowers in late summer or, occasionally, at other times.

X SPIRAEA BUMALDA, "ANTHONY WATERER"

This is the commonest and somewhat over-planted form of a hybrid group. It develops into a two- to three-foot bush with flat, erect clusters of crimson flowers in midsummer. Shearing off of fading flowers will induce a second blooming later in the same season.

SPIRAEA DECUMBENS

A rock-garden Spirea which has few-inch, decumbent stems, small, toothed leaves, and white flower clusters in June.

Spiraea latifolia PINK MEADOW SPIREA

A brown-twigged, coarse-leaved, deciduous native shrub of rocky pastures. With its two to five feet of growth surmounted in summer by open spikes of white flowers, it can find a use in roadside development.

SPIRAEA NIPPONICA var. ROTUNDIFOLIA BIG NIPPON SPIREA

An eight-foot, vigorous, spreading but somewhat stiff-habited, deciduous shrub with smooth, dark-green, rounded, late-persistent leaves. The showy umbels of pure white flowers appear in June about a week later than those of *S. Vanhouttei.* It is valuable because of its superior foliage and ability to withstand dry conditions.

SPIRAEA PRUNIFOLIA var. PLENA DOUBLE BRIDALWREATH

A fine-wooded, prune-leaved, deciduous shrub to eight feet, bearing small, double, white flowers in profusion in May and having shining foliage which turns brilliant orange in autumn.

SPIRAEA THUNBERGII THUNBERG SPIREA

A three- to five-foot, fine-textured, deciduous shrub with slender, arching branches and narrow, filmy leaves. Its tiny, white flowers appear in profusion with the leaves in April or early May. The foliage turns orange and scarlet in autumn. It does well in seashore planting.

Spiraea tomentosa HARDHACK

An erect, gray-leaved, native, deciduous shrub up to some four feet, with pink or purple flowers in crowded panicles in summer. Suitable for wet, open places in wilder areas.

SPIRAEA TRICHOCARPA KOREAN SPIREA

In cultivation this species is looked upon as a coarser, broader, late-flowering supplement of *S. Vanhouttei.* Its larger clusters of flowers coming at the end of June, after *S. nipponica,* serve to extend the flowering season of white Spireas. Like the Philadelphus and other shrubs of this flowering habit, it is not suitable for clipped hedges.

X SPIRAEA VANHOUTTEI VANHOUTTE SPIREA

This hybrid is one of the most beautiful and most abused of our hardy shrubs. When treated properly as the eight-foot, full-bodied, arching-branched, medium-textured shrub which it can be, it is most pleasing. Torture in clipped hedges and frequent planting in too limited areas have made it seem somewhat banal.

Spruce — See Picea

Spurge — See Pachysandra

Stagger-Bush — See Lyonia

Staphylea trifolia AMERICAN BLADDERNUT

An upright, bare-based, native, deciduous shrub to fifteen feet. Of interest in roadside or other wild planting because of bright green foliage, large, inflated, autumn-prominent seed capsules, and ability to withstand a considerable degree of shade.

Stephanandra incisa (*S. flexuosa*) CUTLEAF STEPHANANDRA

Except for the possible value of its small, interesting, deciduous foliage in informal hedgemaking, this species could well give way to *Neillia sinensis.*

STEWARTIA KOREANA

A rare but desirable species which differs from *S. pseudo-camellia* in having larger, broader leaves and flowers borne near or at the ends of the branches. Very definitely a hardy plant.

STEWARTIA PENTAGYNA MOUNTAIN STEWARTIA

A large (ten feet or more), deciduous, American shrub with rounded leaves and white, cup-shaped, three-inch flowers which are borne along the branches in late summer. Its foliage turns orange or red in autumn. A plant for deep, moist or peaty soils and sunny but not too exposed situations. Var. **GRANDIFLORA** has larger flowers, made more showy by purple filaments.

STEWARTIA PSEUDO-CAMELLIA JAPANESE STEWARTIA
A taller-growing species, often of tree-like habit, which has narrower leaves and more open, usually smaller, flowers.

Styrax japonica JAPANESE SNOWBELL
A large, hardy, deciduous shrub or small tree to some thirty feet in height, of garden interest as a specimen or in mixed planting because of its outward-thrusting, slender branches and profuse, hanging, white flowers. Its flowers are showy when seen from below.

Sumac — See Rhus

Sun-Rose — See Helianthemum

Sweet Bells — See *Leucothoe racemosa*

Sweet-Fern — See Comptonia

Sweet Gale — See Myrica

Sweet Gum — See Liquidambar

Sweetleaf — See Symplocos

Sweet-Shrub — See Calycanthus

SYMPHORICARPUS ALBUS var. **LAEVIGATUS** GARDEN SNOWBERRY
A well-known, six-foot, deciduous shrub which has the ability to advance over large areas by suckering. When confined to a small clump, it is of interest because of the prominent, white, autumn fruits which follow the somewhat inconspicuous pinkish flowers of late spring and summer. It could be let loose on rough areas along roadsides in more built-up sections.

X SYMPHORICARPUS CHENAULTII
This upright-growing, well-furnished hybrid makes a distinctly better individual deciduous shrub than does *S. orbiculatus*. Its red-speckled fruits appear in August.

Symphoricarpus orbiculatus (*S. vulgaris*) CORALBERRY
Another quick-spreading, deciduous shrub of greatest value where its suckering proclivities can be put to some use. It can get up to six feet or more in height and always puts on an annual show of prominent red fruits which are enjoyed by birds. White and pink-fruited forms are in cultivation.

SYMPLOCOS PANICULATA ASIATIC SWEETLEAF
Though capable of growing to be forty feet in height, this shrubby, deciduous tree is usually seen in cultivation as a plant perhaps one-third of that height. It appears in gardens as a twiggy plant with interesting foliage, clusters of small, fragrant, white flowers in June, and attractive bluish fruits in autumn. After a few days, the berries are eaten by birds.

X SYRINGA CHINENSIS (*S. rothomagensis*)
A hybrid Lilac which seems to combine in a single plant the gracefulness of *S. persica* and the floriferousness of *S. vulgaris*. A spreading shrub capable of growing to a height of fifteen feet, and bearing intermediate-sized, lilac-purple, slightly fragrant flowers in great profusion towards the end of May. This

species may be had in varieties having white, rosy-lilac, or lilac-red flowers by securing varieties **alba**, **metensis**, or **SAUGEANA**.

X SYRINGA HENRYI, "LUTECE" HENRY LILAC

This hybrid Lilac makes a full, bushy plant resembling *S. villosa* in habit, aspect, and practice of flowering after *S. vulgaris;* but differing by having a larger, looser panicle of violet-purple flowers free of any disagreeable scent.

Syringa japonica JAPANESE TREE LILAC

Though capable of developing into a thirty-foot tree, this species is often seen in cultivation as a ten- or twelve-foot, heavy-wooded shrub. Its creamy-white flowers borne in loose, foot-long panicles give off on the night air of mid-June a scent so heavy that most writers have classed it as unpleasant. Here is a plant which can live happily in dry situations after it has once become established.

SYRINGA PERSICA PERSIAN LILAC

A commonly planted, thin-wooded, small-leaved, small-flowered, graceful shrub reaching a maximum height of some six feet and bearing its pale-lilac, fragrant flowers in broad panicles about the middle of May. Valued as a complete plant and not because of quality of its individual flower trusses. A white-flowered variety is available.

Syringa pubescens HAIRY LILAC

A medium-sized Lilac with a claim to garden value because of the intense fragrance of its profuse, pale-lilac flowers.

SYRINGA REFLEXA NODDING LILAC

Growing to a height of some twelve feet, this rather broad, stout-branched species of somewhat stratified aspect is distinct in that it carries its non-fragrant flowers — carmine in bud and pink when open — in long, hanging panicles at the end of May or early in June. Here is a shrub for use in groups or in edges of the woodland.

SYRINGA VULGARIS COMMON LILAC

This plant and its white variety (var. **alba**) typify the word "Lilac" in the popular mind. Though, by careful handling, both forms can be made to flower quite decently, the inrush of some three hundred garden varieties has relegated them to use as hedging material or as tall ground cover for large, well-drained areas. Usually when so placed the plants vegetate freely and produce but few small flowers.

The very number of hybrid Lilacs and their lack of distinctive characteristics make the result of any attempt at evaluation a highly personalized matter. Perhaps, as it has been said, the best ten are the ten one likes best. In short, selection of Lilac varieties is a matter for personal taste. Thus, the following list of worth-while varieties is offered with no sense of finality but rather as a group of examples of the several expressions of the common Lilac. **"CAVOUR"**, slate-blue, single flowers; **"CHARLES THE TENTH"**, single, reddish-purple; **"CONGO"**, single, dark crimson; **"EDOUARD ANDRE"**, double, pink flowers, open panicle, low-growing plant; **"JAN VAN TOL"**, single, pure white, for forcing; **"LUCIE BALTET"**, single, delicate pink, not free flowering; **"LUDWIG SPAETH"**, single, dark red-purple; **"MME. CASIMER PERRIER"**, single, white, late, free flowering; **"MME. LEMOINE"**, clear white, "hose-in-hose" flowers; **"PRESIDENT FALLIERES"**, double, pale lavender; **"PRESIDENT LINCOLN"**, single, early, bluest of all.

Tamarix pentandra FIVESTAMEN TAMARIX

Slender, flopping branches and fine, scale-like leaves give this large deciduous shrub a decidedly exotic aspect. Not too hardy inland, it can be used effectively for mass planting near the sea. This species flowers in large pink panicles in August and September.

TAXUS BACCATA var. REPANDENS SPREADING ENGLISH YEW

This quite low and broadly spreading variety with its long, dark leaves is one of the hardiest and most commonly planted forms of the English Yew throughout New England. Except in extremely bleak situations it can be used as a low plant to face off groups, or for other similar planting purposes. For such uses it may be looked upon as an improvement over the native *Taxus canadensis.*

Taxus canadensis CANADA YEW

As seen in the wild throughout New England, this native Yew is a straggling, ground-cover plant. As such, it could well be more used in roadside or natural development for clothing shady areas in association with the native Hemlock. In cultivation, however, it thickens up into a rather more compact, fine-textured plant and does reasonably well if given a protected, partially shaded spot. It burns badly in winter in open locations and on such areas should give way to more satisfactory forms of foreign species. Though the type withstands shearing very well, var. STRICTA which is more dense and less vigorous in growth should be selected if a low, sheared hedge of this species is desired.

TAXUS CUSPIDATA JAPANESE YEW

UPRIGHT SEEDLING FORM. This is the upright-growing, multiple-stemmed, type plant such as that usually obtained from seed and generally catalogued by nurserymen as the variety *capitata.* Seedlings of this species show considerable variation and numerous selections have been made and named. For individual specimens almost any of the seedlings are good and are, in general, much hardier than any of the numerous forms of *T. baccata.* However, for plants to be fitted into a close-clipped hedge, it is well to select individuals of about uniform texture, growth-rate, and color. Such upright specimens can be reproduced vegetatively only by making cuttings from true terminal growth which shows a radial distribution of lateral buds. On the whole, however, selection is so well advanced that it is much better to choose the progeny of a desirable clon than to depend on seedlings.

Yews, in general, withstand considerable shearing and in New England will grow quite satisfactorily in light soils furnished with but an ordinary supply of moisture. Under such conditions they will, of course, respond quite favorably to an increased addition of organic material applied as a mulch. In wilder districts they need winter protection from the native deer which avidly seek out the young shoots of the exotic Yews as food.

SPREADING FORM. This is the form produced by rooting dorsi-ventral side-branches of the type plant and may be found listed erroneously as the type. Since seedlings are variable, the plants placed in this category can be no better than the mother plants from which they have been propagated. Thus, here is to be found a mixed population of textures, colors, and, to a certain degree, growth habits. If taken from parent plants of good color, interesting texture, and dense habit, this form of the Yew presents one of the finest and most useful of our free-growing conifers. An ideal plant has its main branches reaching outward and upward and presents an interesting foliage mass which is somewhat broader than tall and is made interestingly irregular in outline by the horizontally extending branchlets.

Var. **DENSA** is perhaps the most dwarf of all the varieties of the Japanese Yew. This slow-growing form lacks the weedy appearance of the Canadian Yew or of *Taxus baccata* var. *repandens.* If unpruned, it will in time develop into a small, compact plant somewhat resembling the spreading form of the type in habit. Suitable for use as a specimen on limited locations or for a low, trimmed hedge.

Var. **"INTERMEDIA"**, though lacking in technical recognition, is a distinct form with rich, dark foliage which very probably has acquired its garden name because it falls about half way between *T. cuspidata* and *T. cuspidata* var. *nana* in texture and rate of growth. Like the type, it has been propagated by the trade from both terminal shoots and side branches and thus may be had in plants of both upright and spreading habit. The fact that a formal description of this variety has never been published is giving rise to much confusion in that the upright form of this particular clon is carelessly listed as *T. cuspidata* var. *intermedia columnaris, T. cuspidata* var. *intermedia capitata,* and under numerous other equally inept names.

Var. **NANA** (*T. brevifolia* of the trade), DWARF JAPANESE YEW, is dense and upright while young, and at maturity displays a dark, interesting foliage mass much broader than its usual height of four to six feet. In nursery sizes it may be considered as standing in growth rate and habit between *T. cuspidata* var. *intermedia* and *T. cuspidata* var. *densa.* Because of relatively slow growth, low stature, and glossier foliage, it is more desirable than spreading plants of the type for permanent use on limited areas.

Var. **"PARSONSII"**, a garden variety not recognized by botanists, is a particularly dark, long-leaved strain of the type, which in southwestern New England has long been grown as an upright plant from terminal cuttings. Though possibly not as hardy as some other forms, its almost black foliage color — particularly fine in winter — makes it desirable. It is sometimes offered in the trade as *T. cuspidata* var. *columnaris, T. cuspidata* var. *intermedia columnaris,* and under other names. Along with it are grown strains of similar narrow upright habit but of a much lighter foliage color.

Var. **THAYERAE** is of rather recent introduction. The type seedling of this plant, because of the somewhat decumbent habit of its several main branches, tends to spread out into a broad mass much greater in horizontal diameter than in height.

X TAXUS MEDIA

In this group fall a number of hybrid forms having technical characters which make them intermediate between *Taxus cuspidata* and *Taxus baccata.* Of the numerous forms of this sort being offered, the following may be mentioned. Var. **HATFIELDII** in its typical form builds up a dense conical bush with upright branches. Var. **"HEDGEFORM"** has a growth rate of some four times that of var. *Hatfieldii* but does not become weedy. Rather, when not crowded, its many vertical stems build up a plant having equal diameters at top and bottom. Var. **HICKSII**, if allowed to grow naturally, will thrust out its many branches to form a bare-based, vase-shaped, open plant. It can, however, when grown to a single leader and heavily sheared, be made into a very formal column, and also makes excellent material for forming clipped hedges. Var. **KELSEYI**, about which little is known in New England, is being touted because of its profuse fruiting properties.

TEUCRIUM CHAMAEDRYS CHAMAEDRYS GERMANDER

An evergreen subshrub with persistent, toothed leaves and stems which reach out and up to form a compact plant some twelve inches high. Much used for very small hedges in warmer sections, but elsewhere considered to be a rock-garden plant.

Thuja occidentalis AMERICAN ARBORVITAE

A familiar native evergreen which has worked its way down from extreme northeastern North America. Usually at its best on non-acid soils. Like all other much-cultivated plants, it has been sorted out in gardens into numerous varieties or clons. Though greater uniformity may be had by use of material propagated from a single desirable parent plant, seedling variation is not so great as to preclude the use of seedling plants for tall screens or clipped hedges on areas having a fertile, well-drained soil. Except for a lack of luster during the winter months, the type Arborvitae stands next to the Yew and the Hemlock as material for evergreen hedge making. Such use demands a type of pruning which will permit the light to strike at the bases and thus prevent destructive shading of the lower branches. The present trend is away from the use of globe-shaped forms which in the past were, in small sizes, much favored for filling up suburban plantings. Var. **COLUMNARIS** differs from the type in being leafier and in having a columnar rather than pyramidal habit. It retains better color in winter, transplants more easily than the type, and makes a dense hedge much more quickly than var. *fastigiata*. Var. **DOUGLASII PYRAMIDALIS** (*T. occ. spiralis*) is a dark, dense, narrow pyramidal form of interest while young because of the crested appearance of its branchlets and good winter color. Var. **FASTIGIATA** (*T. occ. pyramidalis*), PYRAMIDAL AMERICAN ARBORVITAE, is a form with about the same leaf-color as the type, and is much used in formal planting because of its narrow pyramidal habit and ability to retain a pleasant green color during the winter. When used as a hedge plant, an interval of some years may need to elapse before the lateral branches meet to form a close screen. Var. **NIGRA** is a garden form sometimes offered in New England, which improves on the type by carrying a darker summer coloration and not becoming as brown in winter. Var. **ROBUSTA** (*T. occ. Wareana*), WARE ARBORVITAE (SIBERIAN ARBORVITAE), is a dense, slow-growing, broad-based variety with rather rugged-appearing foliage which carries a pleasant bluish-green color through all seasons. It is easily adaptable with a minimum of pruning, for making medium-sized evergreen hedges. Var. **ROSENTHALII**, ROSENTHAL ARBORVITAE, is a broad-based, pyramidal form, valuable because of fine-textured, dark foliage and compact growth. Var. **Wagneri** is a plant of slow growth, egg-shaped habit, and deep gray-green foliage.

THYMUS SERPYLLUM MOTHER-OF-THYME

Here are included a host of botanical and garden forms of prostrate Thymes so useful for planting on banks, in rock gardens, in paths, and for other uses. Numerous forms based on variations of flower color, leaf color, or other properties are available.

TILIA LINDEN

Lindens are, with us, for the most part, a mixed population of seedling plants. There is need for wider use of the practice of vegetative propagation from properly identified and carefully selected parent plants, in order that uniform stocks may be made available. Listed here are some, but not all, of the worthwhile species and clons. In addition to their suitability for use as large trees, the fragrance of their interesting, though inconspicuous, June or July flowers is a property worth consideration.

TILIA CORDATA LITTLE-LEAF EUROPEAN LINDEN

A tall, deciduous tree which is capable of growing to an ultimate height of one hundred feet. Interesting because of its relatively small, two and a half inch, heart-shaped or rounded leaves and very late fragrant flowers.

X TILIA EUCHLORA CRIMEAN LINDEN

A fast-growing, pyramidal hybrid of less ultimate height, but with leaves larger and more lustrous than those of *T. cordata*. Now being used as a street tree. Not generally attacked by aphids.

TILIA TOMENTOSA SILVER LINDEN

A neat-appearing, hundred-foot, deciduous tree of somewhat upright branching habit, which gets its common name from the white, woolly undersurfaces of its five-inch leaves. Being resistant to drought, it is used for street planting or as specimens.

X TILIA VULGARIS COMMON LINDEN

This hybrid of *T. cordata* and the wider-leaved *T. platyphyllos* builds up into a very large, broad, symmetrical, shade tree having dull-green, five-inch leaves. Considered by many as the Linden most suitable for specimen use.

Trailing Arbutus — See Epigaea

Tripterygium Regelii

A half-climbing, deciduous shrub resembling a shrubby plant of Celastrus when not carrying its large panicles of white flowers in midsummer. Useful in dry situations.

Trumpetcreeper — See Campsis

TSUGA CANADENSIS CANADA HEMLOCK

One of the important trends in present-day gardening is the deepening appreciation for eastern American Hemlocks. As seen in sun or shade on acid soil areas in the native landscape, their garden value compares most favorably with that of any of the exotic conifers. Their garden forms, taken together with those of the Yew, can well be made the basis of many fine plantings. Seedlings of the Canada Hemlock, if selected for uniformity of foliage and habit, stand with the Yew and just ahead of the Arborvitae as material for making clipped hedges. Left unpruned, type plants may also be used as specimens and in tall groupings or screens.

Of the seventy or more varieties and habit forms of this species now in cultivation, the following sorts stand out as being representative of its several garden expressions: Var. **ATROVIRENS**, of slow growth and broad habit, has deep-colored foliage arranged on the numerous, somewhat rigid branchlets in such a manner as to give an effect of rigidity and compactness. **"Kelsey's Weeping Variety,"** unlike the common weeping form, develops a more pronounced main stem from which the branching is more definitely pendulous. Var. **MACROPHYLLA** resembles the type in habit but differs from it in having larger, broader leaves. Var. **MINIMA** is a very slow-growing bush for the rock garden. Var. **PENDULA** (SARGENT'S WEEPING HEMLOCK), with horizontal branches and drooping branchlets, builds up into a compact bush of somewhat greater width than height.

TSUGA CAROLINIANA CAROLINA HEMLOCK

A tree of somewhat smaller stature and more compact habit than the Canada Hemlock. If used on cool, moist, well-drained soil, it has greater ultimate cultivated value than the usual type plants, but not of some of the varieties, of the native Hemlock. As a mature specimen, its lacy outline, dark foliage, and attractive cones make it interesting and valuable. In small sizes it does not transplant as readily as the native species. Like the Canada Hemlock, garden varieties are now being selected and tested.

Tsuga diversifolia JAPANESE HEMLOCK

Usually seen in cultivation as a bushy, multiple-leadered specimen with interesting, dark, shining foliage having prominent stomatic bands beneath. It is slow growing and difficult to transplant while young. Not a plant for liberal planting use.

Tulip Tree — See Liriodendron

Tupelo — See Nyssa

Twinflower — See Linnaea

ULMUS AMERICANA AMERICAN ELM

A significant fact about this most familiar of all trees is the way in which it has been able to forget its native alluvium and thrive under difficult street conditions. Whether or not serious insect enemies and the Dutch elm disease will tend to make the use of Elms imprudent, remains to be determined. In nature the Elm takes on numerous different habits, one of which is shown in the "MOLINE ELM" which grows rapidly into a loose column.

Ulmus foliacea var. Wheatleyi JERSEY ELM

A columnar form of the smooth-leaf Elm.

ULMUS PARVIFOLIA CHINESE ELM

A thin-branched, open-headed tree with small leaves which turn red or purple in autumn. Not to be confused with the faster-growing, less desirable *U. pumila.*

ULMUS PROCERA (*U. campestris*) ENGLISH ELM

A large tree which has numerous cultivated varieties. Because it retains its leaves longer in the autumn and, in general, thrives under trying conditions, it has long been considered valuable as a street tree.

Umbrella Pine — See Sciadopitys

VACCINIUM CORYMBOSUM HIGHBUSH BLUEBERRY

Though capable of growing much taller, this familiar native species is usually seen in cultivation as a broad, twiggy, deciduous shrub up to about six feet. Its general rugged aspect, its brilliant autumn foliage display, and the winter interest of its yellow-green or red twigs give it claim to more extensive use in roadside planting or other informal grouping. Its many pomological forms differ only in size and quality of fruit. Its berries offer attraction to birds. Forms based on habit or leaf coloration are in cultivation.

Vaccinium macrocarpum CRANBERRY

In moist, peaty places in wild gardens, this familiar economic plant has possibilities as ground-cover material. It is particularly interesting in autumn while in fruit.

VACCINIUM PENNSYLVANICUM LOWBUSH BLUEBERRY

A variable deciduous shrub of dry or barren hills, which seldom reaches more than two feet in height. Useful as a ground cover or for bank planting. Fruit edible.

Vaccinium Vitis-idaea Cowberry

A low (twelve inches), spreading, evergreen shrub which has rounded shining leaves, white flowers in spring, and dark red berries. An excellent rock-garden shrub offered by the trade in two forms. Var. MAJUS has larger leaves and fruits. Var. MINUS, the Mountain Cranberry, is perhaps half as tall as the type and, likewise, smaller in other parts.

Viburnum acerifolium Maple-Leaf Viburnum

Though not of garden value for flowers or fruit, this native deciduous shrub is useful for bank planting in association with large woodland trees. In the open it will get to be six feet high and put on a bright crimson foliage show in autumn.

VIBURNUM CARLESII Fragrant Viburnum

A broad, spreading, deciduous shrub to five feet, with rounded grayish leaves and dense, three-inch cymes of white, fragrant flowers with the leaves in late April or early May. The fruits are blue-black and not showy. It has suffered in cultivation because (seeds being scarce and cuttings slow) of the questionable practice of grafting on rootstocks of other species. Because of inevitable wild suckering and possible lack of affinity for the understock, own-root plants are much to be preferred.

Viburnum cassinoides Withe-Rod

A tall (six to fifteen feet), native, deciduous shrub of moist land, which was much used in the past in large border plantings. Its leaves are relatively small, plentiful and of shining green. The fruit changes through pink to black. A good thing for suitable roadside locations.

VIBURNUM DENTATUM Arrow-Wood

A tall (ten feet or more at maturity), broad, bushy, deciduous shrub with lustrous, rounded, toothed leaves. Its conspicuous white flowers in three-inch flat heads in late May or early June are followed in autumn by blue-black fruits. Will withstand considerable shade. Fruit eaten by birds.

VIBURNUM DILATATUM Linden Vibburnum

A broad, tall (ten feet or more at maturity), deciduous shrub with rounded, toothed leaves. The white flowers in flattened clusters in late May or early June are followed in autumn by showy, persistent, scarlet fruits. Var. XANTHOCARPUM has yellow fruits.

VIBURNUM FRAGRANS

An upright, deciduous shrub to some nine feet in height with toothed, wedge-shaped leaves on short, colored petioles. The garden value of this plant lies in its small, fragrant, white flowers which open from pinkish buds in April or early May before the leaves appear on the plant.

Viburnum Lantana Wayfaring-Tree

A rather rapid-growing, tall (fifteen feet), often tree-like, deciduous shrub with five-inch, finely toothed, hairy, long-persistent leaves. The white flowers of late May or early June are followed by red fruits which eventually turn black. A plant which can be used to advantage in certain dry situations. Much used of late years as an understock for *V. Carlesii*.

Viburnum prunifolium Black-Haw

A large, bare-based, deciduous shrub or small, multiple-stemmed tree up to some fifteen feet in height. The broad, rounded head of the plant is covered in late April or early May with relatively large, white flower clusters which are followed by large, blue-black, prune-like, edible fruits in autumn. Useful chiefly for natural planting.

VIBURNUM SIEBOLDII SIEBOLD VIBURNUM

Large, tall (ten feet or more), vigorous, deciduous shrub with shiny, rounded, coarsely toothed, long-persistent leaves. The creamy-white flowers in relatively large panicles in late May or early June are followed by fruits which change from pink to blue-black.

VIBURNUM TOMENTOSUM DOUBLEFILE VIBURNUM

A large, broad (six to eight feet), deciduous shrub, interesting in aspect because of the stratified effect created by its horizontally reaching branches from which the leaves hang at a slight angle. The white flowers of late May or early June are in attractive, flattened clusters of fertile flowers rimmed with a margin of more prominent sterile florets. In autumn it has red fruits changing to black on maturity. It requires systematic pruning to make it retain its youthful, pleasing aspect. Var. STERILE (*plicatum*) is the so-called Japanese Snowball which was much planted in the past.

VIBURNUM TRILOBUM (*V. americanum*) CRANBERRY-BUSH

This native, deciduous shrub is considered superior to the European Guelder Rose (*V. Opulus*) for planting in New England. While naturally somewhat gaunt, it is usually, in cultivation, a four- to eight-foot, open but rounded shrub with lobed leaves. The white flowers of May or June are quickly followed by the familiar scarlet fruits which begin to become noticeable in July and cling to the branches throughout the winter.

VIBURNUM WRIGHTII WRIGHT VIBURNUM

A large (about ten feet), deciduous shrub with rounded, toothed leaves which turn red in autumn. Its white flowers of late May or early June are followed by bright red fruits which are probably the showiest of those of any of the Viburnums. In habit this shrub does not make quite such an attractive plant as *V. dilatatum.*

VINCA MINOR, "BOWLES VARIETY"

This is an improved form of the well-known Periwinkle which has proved to be so adaptable for ground cover in sun or shade on either fertile or sterile soil.

Vitex agnus-castus CHASTE-TREE

A "die-back" shrub for warmer sections. If cut to the ground it will grow up as a two- to three-foot, rounded plant, and in late summer of the same season bear dense clusters of pale-violet, fragrant flowers. The variety **alba** bears white flowers. A supposedly hardier and wider-leaved form is in the trade as **V. macrophylla.**

VITIS

Almost any of the Grapes have high garden value for certain locations and conditions. It seems impracticable, however, to list others than those noted below.

VITIS COIGNETIAE (*V. Kaempferi*) GLORYVINE

A strong, hardy, deciduous Grape having abundant large foliage which takes on bright autumn coloration. For leafy covering of arbors etc., or for use as suggested under *Vitis labrusca.*

VITIS LABRUSCA FOX GRAPE

As seen clambering over shrubs, small trees, and fence rows, this native wild Grape becomes one of the pleasant features of our New England roadsides, and should be more used in wilder areas where it need not be confined. Despite cultivated forms, the thick-skinned, sweetish, musky-tasting fruit is valued by some for wine or jelly making. The fruits are also eaten by grouse, pheasant and deer.

VITIS VULPINA RIVERBANK GRAPE

A native, vigorous climber which, in addition to its pleasing foliage, has appeal because of fragrance of male flowers.

Walnut — See Juglans

Wayfaring-Tree — See *Viburnum Lantana*

Weigela — See Diervilla

Willow — See Salix

Winterberry — See *Ilex verticillata*

Wintercreeper — See *Evonymus radicans*

Wintergreen — See Gaultheria

Winterhazel — See Corylopsis

WISTERIA FLORIBUNDA JAPANESE WISTERIA

This species is considered to be superior to *W. sinensis*, with which it is confused in gardens, because of greater hardiness and longer, violet-colored flower clusters. There are numerous garden varieties which, to be true to name, must be propagated vegetatively. That grafting from flowering plants will always insure early flowering remains to be proved. Though generally used as a high-climbing, deciduous vine, Wisteria has great value when grown on low supports or as a well-pruned, runnerless, large shrub. Good forms other than the type are var. **ALBA**, white flowering form with long racemes (up to eighteen inches), which lose their effectiveness if used against the background of a white house; var. **MACROBOTRYS** (*W. multijuga*), LONG-CLUSTER WISTERIA, blue-violet flowers in racemes sometimes up to a yard in length; var. **violaceo-plena**, for those who wish darker, double flowers.

Wisteria nankinensis DWARF WISTERIA

A very dwarf Wisteria which in the rock garden builds up into a quite symmetrical small bush. Its flowers have not yet been seen in American gardens.

Witch-Hazel — See Hamamelis

Withe-Rod — See *Viburnum cassinoides*

Xanthoceras sorbifolia

A heavy-wooded, deciduous shrub or small tree which, at times, grows to a height of fifteen feet or more. It is planted because of its showy racemes of white flowers in May; also, because of its shining, persistent, compound leaves with toothed leaflets.

XANTHORRHIZA SIMPLICISSIMA (*X. apiifolia*) YELLOWROOT

A deciduous shrub with upright stems to about two feet. Spreads by suckers to make a solid ground cover. Its interesting compound leaves unfold with the opening of the terminal, drooping, purplish flowers in early spring. While it can be made to cover a dry bank, it thrives best in somewhat moist, slightly shaded soil.

Yellow-wood — See Cladrastis

Yew — See Taxus

ZENOBIA PULVERULENTA Dusty Zenobia

In cultivation, this eastern coastal plain plant makes a compact, deciduous or semi-evergreen shrub from three to six feet in height with laterally borne clusters of white flowers in June against a background of soft, bluish foliage. It may be characterized as a sour-soil shrub.

Deciduous Trees

Acer carpinifolium
Acer japonicum var. aconitifolium
Acer Negundo
Acer palmatum
Acer pennsylvanicum
ACER PLATANOIDES
ACER PLATANOIDES var. COLUMNARE
ACER RUBRUM
ACER RUBRUM var. COLUMNARE
ACER RUBRUM var. SCHLESINGERI
ACER SACCHARUM
ACER SACCHARUM var. MONUMENTALE
X AESCULUS CARNEA
X Aesculus carnea var. Briotii
X Aesculus carnea var. plantierensis
Aesculus Hippocastanum
Aesculus Hippocastanum var. Baumannii
Ailanthus altissima
AMELANCHIER LAEVIS

BETULA LENTA
Betula nigra
BETULA PAPYRIFERA
BETULA PENDULA var. DALECARLICA
BETULA PENDULA var. FASTIGIATA
Betula populifolia

CARPINUS BETULUS var. FASTIGIATA
CARPINUS CAROLINIANA
CERCIDIPHYLLUM JAPONICUM
CERCIS CANADENSIS
CERCIS CANADENSIS var. ALBA
CHIONANTHUS VIRGINICA
CLADRASTIS LUTEA
CORNUS FLORIDA
CORNUS FLORIDA var. RUBRA
CORNUS FLORIDA var. XANTHOCARPA
CORNUS KOUSA
CORNUS MAS
Corylus Colurna
CRATAEGUS CRUS-GALLI
CRATAEGUS NITIDA
CRATAEGUS OXYACANTHA
CRATAEGUS OXYACANTHA var. PAULII
Crataegus persistens
CRATAEGUS PHAENOPYRUM

FAGUS GRANDIFOLIA
Fagus sylvatica
Fagus sylvatica var. atropunicea
FAGUS SYLVATICA var. FASTIGIATA
Fagus sylvatica var. pendula
Fraxinus americana

GINKGO BILOBA
GINKGO BILOBA var. FASTIGIATA
Gleditsia triacanthos var. inermis
Gymnocladus dioeca

HALESIA MONTICOLA
Halesia monticola var. rosea

Juglans nigra

KOELREUTERIA PANICULATA

LABURNUM ALPINUM
Larix leptolepis
LIQUIDAMBAR STYRACIFLUA
Liriodendron Tulipifera
LIRIODENDRON TULIPIFERA var. PYRAMIDALE
Magnolia acuminata

MAGNOLIA ACUMINATA var. CORDATA
MAGNOLIA DENUDATA
MAGNOLIA SIEBOLDII
X MAGNOLIA SOULANGEANA
X MAGNOLIA SOULANGEANA var. ALBA
X MAGNOLIA SOULANGEANA var. LENNEI
X MAGNOLIA SOULANGEANA var. RUSTICA
Magnolia virginiana
X MALUS ARNOLDIANA
X MALUS ATROSANGUINEA
MALUS FLORIBUNDA
MALUS HUPEHENSIS
Malus ioensis var. plena
Malus pumila var. Niedzwetzkyana
X MALUS PURPUREA var. ELEYI
X Malus Scheideckeri
MALUS SPECTABILIS
MALUS TORINGOIDES
Morus rubra

NYSSA SYLVATICA

OXYDENDRUM ARBOREUM

PHELLODENDRON AMURENSE
PHELLODENDRON SACHALINENSE
X PLATANUS ACERIFOLIA
POPULUS LASIOCARPA
Populus Maximowiczii
Prunus cerasifera var. Pissartii
Prunus Maackii
Prunus maritima
PRUNUS PERSICA var. ALBO-PLENA
Prunus Persica var. atropurpurea
PRUNUS PERSICA var. CAMELLIAEFLORA
PRUNUS PERSICA var. DUPLEX
PRUNUS SARGENTII
PRUNUS SERRULATA, "AMANOGAWA"
PRUNUS SERRULATA var. FUGENZO
PRUNUS SUBHIRTELLA
PRUNUS SUBHIRTELLA var. ASCENDENS
PRUNUS SUBHIRTELLA var. PENDULA
Pseudolarix amabilis

QUERCUS ALBA
QUERCUS BOREALIS
QUERCUS COCCINEA
QUERCUS IMBRICARIA
QUERCUS PALUSTRIS
QUERCUS ROBUR var. FASTIGIATA
QUERCUS VELUTINA

Rhamnus Frangula
RHAMNUS FRANGULA var. LATIFOLIA

Salix alba var. vitellina
Salix babylonica
Salix babylonica var. crispa
SALIX BLANDA
Salix elegantissima
SALIX MATSUDANA var. TORTUOSA
SALIX PENTANDRA
SASSAFRAS ALBIDUM
SOPHORA JAPONICA
SORBUS ALNIFOLIA
SORBUS AUCUPARIA
STEWARTIA KOREANA
STEWARTIA PSEUDO-CAMELLIA
Syringa japonica

TILIA CORDATA
X TILIA EUCHLORA
TILIA TOMENTOSA
X TILIA VULGARIS

ULMUS AMERICANA
ULMUS AMERICANA, "MOLINE ELM"
Ulmus foliacea var. Wheatleyi
ULMUS PARVIFOLIA
ULMUS PROCERA

Evergreen Trees

Abies cilicica
ABIES CONCOLOR
Abies Fraseri
ABIES HOMOLEPIS
ABIES VEITCHII
Chamaecyparis obtusa var. gracilis
Chamaecyparis pisifera
Chamaecyparis pisifera var. filifera
CHAMAECYPARIS PISIFERA var. FILIFERA NANA
Chamaecyparis pisifera var. plumosa

ILEX OPACA

Juniperus chinensis var. columnaris
JUNIPERUS CHINENSIS var. JAPONICA
JUNIPERUS CHINENSIS var. PFITZERIANA
Juniperus communis var. suecica
Juniperus Sabina
JUNIPERUS VIRGINIANA var. CANAERTII
JUNIPERUS VIRGINIANA var. GLAUCA
JUNIPERUS VIRGINIANA var. KETELEERI
Juniperus virginiana var. Schottii

Picea Abies
PICEA ABIES var. CLANBRASILIANA
PICEA ABIES var. GREGORYANA
Picea Abies — See also Rock Garden Plants
PICEA ASPERATA
Picea Engelmanni
PICEA ENGELMANNI var. GLAUCA
PICEA GLAUCA
PICEA GLEHNII
PICEA KOYAMAI
PICEA OMORIKA
PICEA ORIENTALIS
Picea pungens
PICEA PUNGENS var ARGENTEA
Picea pungens var. Kosteriana
PINUS CEMBRA
Pinus densiflora var. umbraculifera
PINUS KORAIENSIS
Pinus nigra
PINUS RESINOSA
PINUS STROBUS
PINUS STROBUS var. FASTIGIATA
Pinus sylvestris
PINUS SYLVESTRIS var. FASTIGIATA
Pinus Thunbergii

PSEUDOTSUGA TAXIFOLIA

SCIADOPITYS VERTICILLATA

TAXUS BACCATA var. REPANDENS
TAXUS CUSPIDATA
TAXUS CUSPIDATA var. "INTERMEDIA"
TAXUS CUSPIDATA var. NANA
TAXUS CUSPIDATA var. "PARSONSII"
TAXUS CUSPIDATA var. THAYERAE
X TAXUS MEDIA var. HATFIELDII
X TAXUS MEDIA, "HEDGE-FORM"
X TAXUS MEDIA var. HICKSII
X TAXUS MEDIA var. KELSEYI
Thuja occidentalis
THUJA OCCIDENTALIS var. COLUMNARIS
THUJA OCCIDENTALIS var. DOUGLASII PYRAMIDALIS
THUJA OCCIDENTALIS var. FASTIGIATA
THUJA OCCIDENTALIS var. NIGRA
THUJA OCCIDENTALIS var. ROBUSTA
THUJA OCCIDENTALIS var. ROSENTHALII
Thuja occidentalis var. Wagneri
TSUGA CANADENSIS
TSUGA CANADENSIS var. ATROVIRENS
Tsuga canadensis, "Kelsey's Weeping Variety"
TSUGA CANADENSIS var. MACROPHYLLA
TSUGA CANADENSIS var. PENDULA
TSUGA CAROLINIANA
Tsuga diversifolia

Plants for Ground Covering, Bank Planting and Under Planting

ACTINIDIA ARGUTA
AMELANCHIER STOLONIFERA
ARCTOSTAPHYLOS UVA-URSI

Baccharis halimifolia

CALLUNA VULGARIS
Ceanothus americanus
CELASTRUS ORBICULATA
Chaenomeles japonica var. alpina
Chamaedaphne calyculata

CLEMATIS PANICULATA
COMPTONIA ASPLENIIFOLIA
Corylus cornuta
COTONEASTER ADPRESSA
COTONEASTER APICULATA
COTONEASTER HORIZONTALIS
COTONEASTER HORIZONTALIS var. PERPUSILLA

Diervilla Lonicera
Diervilla sessilifolia

EVONYMUS OBOVATA
EVONYMUS RADICANS
Evonymus radicans var. acuta
EVONYMUS RADICANS var. COLORATA
EVONYMUS RADICANS var. MINIMA
EVONYMUS RADICANS var. VEGETA

Gaylussacia baccata
GAYLUSSACIA BRACHYCERA

HEDERA HELIX var. BALTICA
Hippophae rhamnoides
Hydrangea arborescens
Hypericum Buckleyi
Hypericum calycinum
HYPERICUM KALMIANUM

INDIGOFERA KIRILOWII

JUNIPERUS CHINENSIS var. SARGENTII
Juniperus communis var. depressa
JUNIPERUS CONFERTA
JUNIPERUS HORIZONTALIS var. DOUGLASII
JUNIPERUS HORIZONTALIS var. GLAUCA
JUNIPERUS HORIZONTALIS var. PLUMOSA
Juniperus procumbens

Kalmia angustifolia

Lonicera Henryi
LONICERA JAPONICA var. HALLIANA
LONICERA PILEATA
LONICERA SPINOSA var. ALBERTI
LONICERA THIBETICA
Lycium chinense
Lyonia mariana

Mahonia repens
MITCHELLA REPENS
Myrica Gale
MYRICA PENNSYLVANICA

PACHISTIMA CANBYI
PACHYSANDRA TERMINALIS
Phlox subulata in variety
Pinus mugo
Pinus mugo var. Mughus
Potentilla fruticosa
Prunus pumila var. depressa

RHUS CANADENSIS
Rosa arvensis
ROSA CAROLINA
ROSA NITIDA
X Rosa Paulii
X ROSA RUGOSA, "MAX GRAF"
ROSA SETIGERA
X ROSA "SKYROCKET"
ROSA WICHURAIANA
X ROSA WICHURAIANA
  "ALBERIC BARBIER"
  "AVIATEUR BLERIOT"
  "EVERGREEN GEM"
  "FRANCOIS POISSON"
  "SANDERS WHITE"
Rubus Cockburnianus
RUBUS DELICIOSUS
Rubus odoratus

Salix humilis
Salix retusa
Salix tristis
Sorbaria sorbifolia
Spiraea latifolia
Spiraea tomentosa
SYMPHORICARPUS ALBUS var. LAEVIGATUS
Symphoricarpus orbiculatus

Taxus canadensis
THYMUS SERPYLLUM

Vaccinium macrocarpum
VACCINIUM PENNSYLVANICUM
Viburnum acerifolium
VINCA MINOR, "BOWLES VARIETY"

XANTHORRHIZA SIMPLICISSIMA

Woody Plants for Rock Gardens

AETHIONEMA GRANDIFLORUM
Alyssum argenteum
ALYSSUM SAXATILE var. COMPACTUM
Andromeda glaucophylla
ARCTOSTAPHYLOS UVA-URSI
Ascyrum hypericoides

BERBERIS BUXIFOLIA var. PYGMAEA
Berberis candidula
Betula nana
Bruckenthalia spiculifolia

CALLUNA VULGARIS
CALLUNA VULGARIS var. ALBA
CALLUNA VULGARIS var. ALPORTII
CALLUNA VULGARIS var. CARNEA
Calluna vulgaris var. cuprea
CALLUNA VULGARIS var. HAMMONDII
Calluna vulgaris var. hirsuta
CALLUNA VULGARIS var. NANA
CALLUNA VULGARIS var. RIGIDA
Calluna vulgaris var. rubra
Calophaca wolgarica
Calycanthus fertilis var. nanus
Caragana arborescens var. nana
Cassiope hypnoides
Cassiope tetragona
Chaenomeles japonica var. alpina
CHAMAECYPARIS OBTUSA var. NANA
CHAMAECYPARIS OBTUSA var. PYGMAEA
Chiogenes hispidula
Clinopodium georgianum
Corema Conradii
Cornus canadensis
COTONEASTER ADPRESSA
COTONEASTER APICULATA
COTONEASTER DAMMERI var. RADICANS
COTONEASTER HORIZONTALIS
COTTONEASTER MICROPHYLLA var. THYMIFOLIA
Cytisus Ardoinii
Cytisus decumbens
X CYTISUS KEWENSIS

Daboecia cantabrica
Daphne Blagayana
DAPHNE CNEORUM
DAPHNE CNEORUM var. ALBA
DAPHNE GENKWA
DAPHNE PETRAEA
Diapensia lapponica
DRYAS DRUMMONDII
DRYAS OCTOPETALA

Empetrum nigrum
Ephedra distachya
Ephedra equisetina
EPIGAEA REPENS
ERICA CARNEA
ERICA TETRALIX
ERICA VAGANS
ERICA VAGANS var. KEVERNENSIS
Escallonia virgata
Evonymus nana
EVONYMUS RADICANS var. MINIMA

FOTHERGILLA GARDENI

GAULTHERIA PROCUMBENS
GAYLUSSACIA BRACHYCERA
Genista hispanica
GENISTA PILOSA
GENISTA SAGITTALIS

HEDERA HELIX var. CONGLOMERATA
Hedera helix var. minima
HELIANTHEMUM NUMMULARIUM
Hudsonia montana
Hypericum Buckleyi

IBERIS SEMPERVIRENS
IBERIS SEMPERVIRENS, "LITTLE GEM"
Ilex rugosa
JUNIPERUS CHINENSIS var. SARGENTII
Juniperus communis var. depressa
JUNIPERUS CONFERTA
JUNIPERUS HORIZONTALIS var. DOUGLASII
JUNIPERUS HORIZONTALIS var. GLAUCA
JUNIPERUS HORIZONTALIS var. PLUMOSA
Juniperus procumbens

KALMIA ANGUSTIFOLIA var. PUMILA
Kalmia polifolia

LAVANDULA SPICA
LEDUM GROENLANDICUM
LEDUM GROENLANDICUM var. COMPACTUM
LEIOPHYLLUM BUXIFOLIUM
LEIOPHYLLUM BUXIFOLIUM var. HUGERI
LEIOPHYLLUM BUXIFOLIUM var. PROSTRATUM
Linnaea borealis var. americana
LITHOSPERMUM DIFFUSUM
LOISELEURIA PROCUMBENS
LONICERA PILEATA

MITCHELLA REPENS
Muehlenbeckia axillaris

Opuntia humifusa

PACHISTIMA CANBYI
PENTSTEMON SCOULERI
Phlox bifida
X PHLOX SUBULATA, NON-SPREADING VARIETIES
Phyllodoce coerulea
Phyllodoce empetriformis
X Phyllothamnus erectus
PICEA ABIES var. MAXWELLII
PICEA ABIES var. NIDIFORMIS
PICEA ABIES var. PROCUMBENS
PICEA ABIES var. PYGMAEA
PICEA ABIES var. REPENS
PICEA ABIES var. TABULIFORMIS
Picea glauca var. conica
PINUS MUGO var. COMPACTA
PINUS MUGO var. SLAVINII
PINUS SYLVESTRIS var WATERERI
POLYGALA CHAMAEBUXUS
Pyxidanthera barbulata

Rhamnus pumila
RHODODENDRON INDICUM var. BALSAMINAEFLORUM
Rhododendron lapponicum
Rhododendron racemosum
ROSA NITIDA
ROSA ROULETTII

Salix herbacea
Salix reticulata
Salix retusa
Salix uva-ursi
Sarcococca Hookeriana var. humilis
Sasa pygmaea
Sedum populifolium
SPIRAEA BULLATA
SPIRAEA DECUMBENS

TAXUS CANADENSIS var. STRICTA
TAXUS CUSPIDATA var. DENSA
TEUCRIUM CHAMAEDRYS
THYMUS SERPYLLUM
TSUGA CANADENSIS var. MINIMA

VACCINIUM VITIS-IDAEA var. MAJUS
VACCINIUM VITIS-IDAEA var. MINUS

Wisteria nankinensis

Plants of Shrub-Like Habit

X Abelia grandiflora
ACANTHOPANAX SIEBOLDIANUS
Acer japonicum var. aconitifolium
Acer palmatum
Acer spicatum
Acer tataricum
Aesculus parviflora
AMELANCHIER CANADENSIS
AMELANCHIER STOLONIFERA
ARONIA ARBUTIFOLIA
Aronia melanocarpa
ARONIA MELANOCARPA var. ELATA
Baccharis halimifolia
BERBERIS AMURENSIS var. JAPONICA
Berberis dictyophylla
Berberis Julianae
BERBERIS KOREANA
X BERBERIS MENTORENSIS
BERBERIS THUNBERGII
Berberis Thunbergii var. atropurpurea
BERBERIS THUNBERGII var. ERECTA
BERBERIS THUNBERGII var. MINOR
Berberis triacanthophora

BERBERIS VERNAE
Berberis verruculosa
BERBERIS VULGARIS
BUDDLEIA ALTERNIFOLIA
Buddleia Davidi var. nanhoensis
BUDDLEIA DAVIDI var. VEITCHIANA
BUDDLEIA, "ISLE DE FRANCE"
Buxus microphylla var. koreana
Buxus sempervirens
Buxus sempervirens var. suffruticosa

Callicarpa dichotoma
CALLICARPA JAPONICA
Calycanthus floridus
Caryopteris incana
Cephalanthus occidentalis
CHAENOMELES JAPONICA
CHAENOMELES LAGENARIA
CHIONANTHUS VIRGINICA
Clerodendron trichotomum
Clethra acuminata
CLETHRA ALNIFOLIA
Clethra alnifolia var. rosea
Clethra barbinervis
CORNUS ALBA var. SIBIRICA
CORNUS ALTERNIFOLIA
CORNUS MAS
CORNUS RACEMOSA
CORNUS STOLONIFERA
Cornus stolonifera var. flaviramea
CORYLOPSIS PAUCIFLORA
Corylus Avellana var. contorta
Corylus cornuta
Cotinus coggygria
COTONEASTER DIELSIANA
Cotoneaster Dielsiana var. elegans
Cotoneaster Dielsiana var. major
COTONEASTER DIVARICATA
COTONEASTER FOVEOLATA
COTONEASTER HUPEHENSIS
COTONEASTER RACEMIFLORA var. SOONGORICA
Cotoneaster salicifolia var. floccosa
Cytisus scoparius
Cytisus scoparius var. Andreanus

DAPHNE MEZEREUM
DAPHNE MEZEREUM var. ALBA
DEUTZIA GRACILIS
X DEUTZIA LEMOINEI, "BOULE DE NEIGE"
X Deutzia rosea var. campanulata
Deutzia scabra var. Watereri
DIERVILLA FLORIDA var. VENUSTA
X Diervilla hybrida
"Abel Carriere"
"Candida"
"Congo"
"Eva Rathke"
Diervilla praecox
DIRCA PALUSTRIS

Elaeagnus angustifolia
ELSHOLTZIA STAUNTONI
ENKIANTHUS CAMPANULATUS
ENKIANTHUS PERULATUS
EVONYMUS ALATA
EVONYMUS ALATA var. COMPACTA
EVONYMUS EUROPAEA
EVONYMUS RADICANS var. CARRIEREI
EVONYMUS YEDOENSIS
EXOCHORDA GIRALDII
EXOCHORDA GIRALDII var. WILSONII

X FORSYTHIA INTERMEDIA var PRIMULINA
X FORSYTHIA INTERMEDIA var. SPECTABILIS
Forsythia ovata
Forsythia suspensa var. Sieboldii
FOTHERGILLA MONTICOLA

GORDONIA ALATAMAHA

HALESIA MONTICOLA
Halesia monticola var. rosea
HAMAMELIS MOLLIS
HAMAMELIS VERNALIS
HAMAMELIS VIRGINIANA
Hibiscus syriacus
"Ardens"
"Banner"
"Boule de Feu"
"Coelestis"
"Duc de Brabant"
"Jeanne d'Arc"
"Lucy"
"Rubis"
"Totus Albus"
HYDRANGEA ARBORESCENS var. GRANDIFLORA
HYDRANGEA MACROPHYLLA var. COERULEA
HYDRANGEA PANICULATA
HYDRANGEA PANICULATA var. PRAECOX
HYPERICUM AUREUM
Hypericum prolificum

ILEX CRENATA var. CONVEXA
ILEX GLABRA
ILEX VERTICILLATA

KALMIA LATIFOLIA
KALMIA LATIFOLIA var. MYRTIFOLIA
Kerria japonica
KERRIA JAPONICA var. PLENIFLORA
KOLKWITZIA AMABILIS

LESPEDEZA THUNBERGII
LEUCOTHOE CATESBAEI
Leucothoe racemosa
LIGUSTRUM AMURENSE
X LIGUSTRUM IBOLIUM
LIGUSTRUM OBTUSIFOLIUM var. REGELIANUM
Lindera aestivale
LONICERA FRAGRANTISSIMA
LONICERA KOROLKOWII var. FLORIBUNDA
LONICERA MAACKII var. PODOCARPA
LONICERA MORROWII
LONICERA MORROWII var. XANTHOCARPA
LONICERA TATARICA var. ROSEA

MAGNOLIA STELLATA
MAGNOLIA STELLATA var. ROSEA
Mahonia Aquifolium
MALUS SARGENTI
Myrica Gale

Neillia sinensis
Nemopanthus mucronata

PAEONIA SUFFRUTICOSA
PHILADELPHUS CORONARIUS
X PHILADELPHUS CYMOSUS, "NORMA"
X PHILADELPHUS LEMOINEI, "AVALANCHE"
X PHILADEPHUS MAXIMUS
X PHILADELPHUS SPLENDENS
X PHILADELPHUS VIRGINALIS, "VIRGINAL"
Photinia villosa var. laevis
PIERIS FLORIBUNDA
PIERIS JAPONICA
PRUNUS TOMENTOSA
Prunus triloba
PRUNUS TRILOBA var. PLENA

RHODODENDRON ARBORESCENS
X RHODODENDRON ARBUTIFOLIUM
RHODODENDRON CALENDULACEUM
Rhododendron canadense
RHODODENDRON CAROLINIANUM
RHODODENCRON CAROLINIANUM var. ALBUM
RHODODENDRON CATAWBIENSE
RHODODENDRON CATAWBIENSE var. COMPACTUM
RHODODENDRON, EVERGREEN HYBRIDS.
  "ALBUM ELEGANS"
  "ATROSANGUINEUM"
  "BOULE DE NEIGE"
  "CATAWBIENSE ALBUM"
  "CHARLES DICKENS"
  "DELICATISSIMUM"
  "EVERESTIANUM"
  "LADY ARMSTRONG"
  "MRS. CHARLES SARGENT"
  "PURPUREUM GRANDIFLORUM"
X Rhododendron gandavense
  "Daviesii"
  "Dulcinee"
  "Pallas"
  "Unique"
  "Bijou de Gandbruges"
  "Raphael de Smet"
RHODODENDRON JAPONICUM
RHODODENDRON JAPONICUM var. AUREUM
X Rhododendron Kosterianum, "Miss Louisa Hunnewell"
X RHODODENDRON LAETEVIRENS
RHODODENDRON MAXIMUM
Rhododendron minus
RHODODENDRON MUCRONULATUM
X RHODODENDRON MYRTIFOLIUM
RHODODENDRON OBTUSUM var. KAEMPFERI
RHODODENDRON ROSEUM
RHODODENDRON SCHLIPPENBACHII
RHODODENDRON SMIRNOWII
RHODODENDRON VASEYI
RHODODENDRON YEDOENSE var. POUKHANENSE
RHODOTYPUS SCANDENS
RHUS COPALLINA

- RHUS GLABRA
- Rhus typhina
- ROBINIA KELSEYI
- Rosa acicularis
- Rosa blanda
- ROSA EGLANTERIA
- Rosa gallica
- X ROSA HARISONII
- ROSA HUGONIS
- X ROSA, “HYBRID PERPETUALS”
  - “BARONESS ROTHSCHILD”
  - “BARONNE PREVOST”
  - “HORACE VERNET”
  - “JULES MARGOTTIN”
  - “LOUIS VAN HOUTTE”
  - “SUZANNE-MARIE RODOCANACHI”
- X ROSA, “POLYANTHA ROSES”
  - “KIRSTEN POULSEN”
  - “MARIE PAVIC”
  - “MRS. R. M. FINCH”
  - “SALMON SPRAY”
- ROSA PRIMULA
- Rosa rubrifolia
- ROSA RUGOSA
- ROSA RUGOSA var. ALBO-PLENA
- ROSA RUGOSA var. PLENA
- X ROSA RUGOSA
  - “AGNES”
  - “AMELIE GRAVEREAUX”
  - “DR. ECKENER”
  - “F. J. GROOTENDORST”
  - “NEW CENTURY”
  - “NOVA ZEMBLA”
  - “PINK GROOTENDORST”
  - “ROSE A PARFUM DE L’HAY”
  - “SARAH VAN FLEET”
  - “SCHNEEZWERG”
  - “SIR THOMAS LIPTON”
  - “STERN VON PRAG”
  - “VANGUARD”
- ROSA SPINOSISSIMA var. ALTAICA
- ROSA VIRGINIANA
- Rosa Webbiana

- SAMBUCUS CANADENSIS
- SAMBUCUS PUBENS
- Sambucus racemosa
- X SPIRAEA BUMALDA, “ANTHONY WATERER”
- SPIRAEA NIPPONICA var. ROTUNDIFOLIA
- SPIRAEA PRUNIFOLIA var. PLENA
- SPIRAEA THUNBERGII
- SPIRAEA TRICHOCARPA
- X SPIRAEA VANHOUTTEI
- Staphylea trifolia
- Stephanandra incisa
- STEWARTIA KOREANA
- STEWARTIA PENTAGYNA
- STEWARTIA PENTAGYNA var. GRANDIFLORA
- STEWARTIA PSEUDO-CAMELLIA
- Styrax japonica
- SYMPHORICARPUS ALBUS var. LAEVIGATUS
- X SYMPHORICARPUS CHENAULTII
- Symphoricarpus orbiculatus
- Symplocos paniculata
- X SYRINGA CHINENSIS
- X SYRINGA HENRYI, “LUTECE”
- Syringa japonica
- SYRINGA PERSICA
- Syringa pubescens
- SYRINGA REFLEXA
- SYRINGA VULGARIS
- Syringa vulgaris var. alba
- X SYRINGA VULGARIS
  - “CAVOUR”
  - “CHARLES THE TENTH”
  - “CONGO”
  - “EDOUARD ANDRE”
  - “JAN VAN TOL”
  - “LUCIE BALTET”
  - “LUDWIG SPAETH”
  - “MME. CASIMER PERRIER”
  - “MME. LEMOINE”
  - “PRESIDENT FALLIERES”
  - “PRESIDENT LINCOLN”

- Tamarix pentandra
- Tripterygium Regelii

- VACCINIUM CORYMBOSUM
- VIBURNUM CARLESII
- Viburnum cassinoides
- VIBURNUM DENTATUM
- VIBURNUM DILATATUM
- VIBURNUM DILATATUM var. XANTHOCARPUM
- VIBURNUM FRAGRANS
- Viburnum Lantana
- Viburnum prunifolium
- VIBURNUM SIEBOLDII
- VIBURNUM TOMENTOSUM
- VIBURNUM TOMENTOSUM var. STERILE
- VIBURNUM TRILOBUM
- VIBURNUM WRIGHTII

Vitex agnus-castus
Vitex agnus-castus var. alba
Vitex "Macrophylla"

Xanthoceras sorbifolia

ZENOBIA PULVERULENTA

Vines

ACTINIDIA ARGUTA
AKEBIA QUINATA
AMPELOPSIS ACONITIFOLIA
AMPELOPSIS BREVIPEDUNCULATA
Ampelopsis brevipedunculata var. elegans
Aristolochia durior

CAMPSIS RADICANS
Campsis radicans var. atropurpurea
Campsis radicans var. flava
Campsis radicans var. speciosa
X Campsis Tagliabuana, "Mme. Galen"
CELASTRUS ORBICULATA
CELASTRUS SCANDENS
CLEMATIS HYBRIDS
  "Crimson King"
  "DUCHESS OF ALBANY"
  "GYPSY QUEEN"
  "JACKMANI"
  "JOUINIANA"
  "HENRYI"
  "MME. EDOUARD ANDRE"
  "MRS. CHOLMONDELEY"
  "NELLIE MOSER"
  "PRINS HENDRIK"
CLEMATIS MACROPETALA
CLEMATIS MONTANA var. RUBENS
CLEMATIS PANICULATA
CLEMATIS TANGUTICA
CLEMATIS TEXENSIS
Clematis virginiana
CLEMATIS VITICELLA var. KERMESINA

Decumaria barbara

EVONYMUS RADICANS
EVONYMUS RADICANS var. VEGETA
HEDERA HELIX var. BALTICA
HYDRANGEA PETIOLARIS

LONICERA HECKROTTII
Lonicera Henryi
LONICERA JAPONICA var. HALLIANA
LONICERA SEMPERVIRENS var. SULPHUREA
LONICERA SEMPERVIRENS var. SUPERBA

Parthenocissus quinquefolia var. Engelmanii
PARTHENOCISSUS TRICUSPIDATA
PARTHENOCISSUS TRICUSPIDATA var. LOWII
POLYGONUM AUBERTII

Schizophragma hydrangeoides
Smilax rotundifolia

VITIS COIGNETIAE
VITIS LABRUSCA
VITIS VULPINA
WISTERIA FLORIBUNDA
WISTERIA FLORIBUNDA var. ALBA
WISTERIA FLORIBUNDA var. MACROBOTRYS
Wisteria floribunda var. violaceo-plena

Publication of this Document Approved by Commission on Administration and Finance
7,500. 9-'37. No. 1832.

WESBY & SONS
OCT
1956